Proceedings of the 62nd Annual Convention of the American Association of Equine Practitioners

Orlando, Florida
December 3–7

Program Chair: R. Reynolds Cowles, Jr., DVM

ACKNOWLEDGMENTS
P.O. Eric Mueller, DVM, PhD, DACVS, Educational Programs Committee Chair
Carey M. Ross, Scientific Publications Coordinator

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Policy Statement

The primary purpose of publishing the Proceedings is to provide documentation of the scientific presentations in abstract form, available at the AAEP annual convention. Its further purpose is to offer easily accessible information that will assist the AAEP membership, and others in the equine industry, in the daily responsibility of providing the best possible care for the horse.

Mission Statement

To improve the health and welfare of the horse, to further the professional development of its members, and to provide resources and leadership for the benefit of the equine industry.

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Want to know how your AAEP Annual Convention program came together?

The Educational Programs Committee (EPC) is charged with creating and reviewing educational content to produce high-quality CE for the AAEP. The committee is composed of AAEP member volunteers from both small and large private practices as well as academia and industry. Members include both general practitioners and specialists.

The Orlando program includes invited papers for the “In-depth” and “How to” sessions as well as sessions comprised of papers that independent authors submitted for consideration. Topic choices for the invited “In Depth” and “How To” sessions are based on member feedback from the 2010 & 2015 AAEP CE Needs Analysis surveys. Topic session leaders are selected by the Program Chair, and then these session leaders invite a slate of speakers to prepare the papers that become an “In Depth” overview or a series of related “How To” talks. Although invited, these papers undergo a rigorous peer review process by the EPC.

Papers submitted by independent authors are each assigned 3 reviewers from the EPC. The reviewers do not know the names of the authors. Content is scored using the criteria of Study Design, Study Quality, Innovation and Impact, Practicality, and Manuscript Quality. Once papers are scored they are discussed by the section facilitators and reviewers. The highest ranking papers are included on the program to accommodate the number of slots available. This year 165 papers were submitted for the 55 available slots on the program.

Non-scientific sessions addressing business, welfare, ethical and industry concerns are also planned as the scientific program materializes. Speakers who are invited to participate in these sessions prepare papers that are also reviewed by members of the EPC for inclusion in the Proceedings.

The peer review process for the AAEP Proceedings requires an enormous effort by more than 50 members of the EPC to create the best possible program for the AAEP membership. Several thousand volunteer hours were spent putting together the Orlando program, so please thank them for all their hard work creating this program for you.
Dear AAEP Members & Guests:

It is my pleasure to welcome you all to Orlando and the AAEP 62nd Annual Convention. I hope you find that there is something “magical” for all here in the home of the Magic Kingdom of Disney . . .

The 2016 Program Chair and President-Elect, Dr. Reynolds Cowles, has woven together an excellent science based practitioner program but he has also left room for us to consider the “art” of veterinary practice with a strong discussion focus in several critical topics such as ethical practice. A round of thanks goes to all who worked hard to create this program: the entire Educational Programs Committee, AAEP staff and the leaders Drs. Eric Mueller, Phoebe Smith and Ed Kanara – THANK YOU!

As you explore the convention venue please take time to thank our Educational Partners in the Trade Show – AAEP recognizes their positive role both here this week, and throughout the year, with their efforts to support our mission of improving the health and welfare of the horse through product/technology and education of you, the “horse doctors.”

It has been an outstanding year for AAEP – I have been privileged to work with many of you in multiple capacities from the Board of Directors to the strong committees, councils and task forces that are in place to ensure we continue to move forward in multiple areas of engagement. The 2020 Strategic Plan continues to focus on five essential areas for the Member: Benefits, Wellness, Continuing Education, Communication and Advocacy. You will continue to hear more about these efforts as the year closes and another begins but rest assured your AAEP is working hard for you.

Thank you to each and every one of you for your commitment to the horse – we are their stewards, and it is with both honor and responsibility that we all serve that purpose in many varied roles. I encourage you to keep up the good work and enjoy all that this convention has to offer in education and fellowship.

“If you are successful in life, it is because somewhere, sometime, someone gave you a life or an idea that started you in the right direction. Remember also that you are indebted to life until you help some less fortunate just as you were helped.” Melinda Gates or in simpler terms: We are all in this together!

Best wishes for a great 2016 Convention!

Kathleen M. Anderson, DVM
AAEP 2016 President
Greetings AAEP Members, Students and Colleagues!

As program chair for 2016, I welcome you to Orlando and invite you to “Make a Splash”. The Educational Programs Committee, under the direction of Dr. Eric Mueller, Dr. Phoebe Smith, Mrs. Carey Ross and its very dedicated members, has put together a program for all. The EPC has made this a very practical program and we have presentations that will give everyone something to take home to improve your practice.

Highlights include:

- **Keynote Speaker** – Chuck Gallagher, a nationally known speaker on Practical Ethics. The membership has asked for ethical education in the latest member survey and we bring you some startling reasons as to “Why Normally Smart People Do Unethical Things.” This will be followed by a panel discussion among leading practitioners on the subject, “Can Horse Show/Racetrack Practice Be Ethical?”
- **Kester News Hour** – Our participants will bring you candid updates in leading information with their usual hard hitting style.
- **Milne Lecture** – Dr. Norm Ducharme will give us everything we need to know about the Upper Airway.
- **Wellness** – Debt management for all. Tools for prevention and cure.
- **In-Depth Sessions** – from Practical Applications of MRI results to Lameness Rehab and Infectious Disease.
- **How-to-Sessions** – on Treating the Subfertile Mare, How to Feed the Special Needs Horse, Life Stage Management and Basic Dentistry.
- **Abstract Sessions** – covering lameness, surgery, respiratory disease, and reproduction.
- **Business Sessions** – featuring the theme of “Transitions” - from student to practice, to midlife, to retirement and selling your practice. The featured model is the Littleton Equine Clinic as the lead off speaker - don’t miss it.
- **A Very Large Trade Show** – where you can find and interact with all your suppliers and colleagues and see what is new.
- **An Expanded Student Program** – concentrated on the weekend for access.
- **Table Topics** – galore covering everything from clinical techniques to insurance conflicts and cyberbullying.

R. Reynolds Cowles, Jr., DVM
2016 President-Elect and Program Chair
2016 AAEP Board of Directors

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Kathleen M. Anderson, DVM

**Executive Director**
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2016 AAEP Awards

**Distinguished Life Member** – Dr. Glenn P. Blodgett
The AAEP Distinguished Life Member designation is awarded in recognition and appreciation of dedication and meritorious service to the veterinary profession and the advancement of equine medicine.

**Distinguished Educator Award (Academia)** – Dr. Dennis E. Brooks
Awarded to an individual educator who by their actions and commitment has demonstrated a significant impact on the development and training of equine practitioners.

**Distinguished Service Award** – Dr. William A. Moyer
Awarded to an individual who has provided exemplary service to the AAEP or a similar organization to the benefit of the horse, horse industry, or the profession of equine veterinary medicine.

**The Lavin Cup** – Mr. Michael Blowen
Named for AAEP past president, A. Gary Lavin, VMD, this award is presented to a non-veterinary individual or organization that has demonstrated exceptional compassion or developed and enforced rules and guidelines for the welfare of the horse.

**George Stubbs Award** – Mr. James J. (Jay) Hickey, Jr.
This award recognizes outstanding contributions made to equine veterinary medicine by an individual other than a veterinarian.
General Instructions for Authors
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017

To submit a paper, go to https://aaep2017.abstractcentral.com/
ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.

The AAEP Proceedings is protected by copyright and information submitted and accepted becomes the property of AAEP. However, requests for copies or reprints will be honored by AAEP only with the cooperative permission of the presenting author, who by his or her presentation represents all authors. AAEP reserves the right not to accept any submission without further recourse.

Presentations for the AAEP Convention will be selected directly from the review-ready submissions to the AAEP. Submissions may include case series with follow-up data, or the results of experimental or observational studies as scientific papers, as well as “How to” and review papers. Selection will be made by the Educational Programs Committee. The quality of the submission will determine the selection. Missing data or proposed, but not completed procedures, will exclude the submission from consideration. AAEP invites information dealing with any subject germane to equine practice, but special consideration will be given to submissions by practitioners and material with practical content or new information. At least one author of a report describing diagnosis, treatment, or the interpretation of medical information should be a veterinarian.

All submissions should strictly adhere to the Instructions for Authors. Submissions will be ranked using the AAEP Scoring Criteria (found in the Scoring Criteria section) and the highest-ranking papers will be selected for the available time.

Authors are expected to acknowledge all sources of funding or support for the work described and to disclose to the Educational Programs Committee any financial interest (including ownership, employment, consultancy arrangements, or service as an officer or board member) they have with companies that manufacture or sell products that figure prominently in the paper or with companies that manufacture or sell competing products. Such an interest will not necessarily influence the decision to accept or reject a submission for the program, but must be included in the Acknowledgments section for the convention proceedings.

Guidelines:
Failure to adhere to the following format will result in non-acceptance. It is the author’s responsibility to convince the Educational Programs Committee of the value of the submission, as well as to portray to the reader the contents of the presentation. Specific instructions for Scientific papers, “How to” papers, Review papers, ≤ 250 word abstracts, and Business papers, and can be found in their respective sections.

Format:
- 12 point font size
- Double-spaced
- 1” margins
- Times New Roman font
- The paper must be submitted as a .pdf.

Headings should include (but are not limited to) the following:
1. Take Home Message
2. Introduction
3. Materials and Methods
4. Results
5. Discussion
6. Acknowledgments
   i. Declaration of Ethics
   ii. Conflicts of Interest
7. References

Title:
The title should be 15 words or fewer, at the top and on the first page.

Example:
Upper Respiratory Dysfunction in Horses During High Speed Exercise

Take Home Message:
This should be a short, concise summarization of the main conclusion and should be no longer than two or three sentences (approximately 50 words). "How to" papers do not require a take-home message.

Example:
Local anesthetic injected into the coffin joint is not selective for only this joint. Such injections will desensitize much of the navicular bone and its suspensory ligaments.

Introduction:
The rationale for the submission should be given briefly and significant published work acknowledged here. The clinical significance should also be included, as well as a clear statement of the objective or purpose of the submission. The statement of objectives is usually found in the last sentence of the Introduction.

Materials and Methods:
This section should describe experimental methodology in the case of a didactic study or, in the case of a clinical study, should include a description of the population from which the animals were selected and how they were selected for inclusion in the report.

Data obtained and how they were obtained must be described. A description of the statistical methods used to summarize data, test hypotheses, and characterize the significance of results should also be included. For weights and measures, metric units should be used. Dosages should be expressed entirely in metric units and with specific time intervals.
Results:
Actual results with numbers and data must be presented. When possible, quantify findings (mean, median, proportion) and present them with appropriate estimates of measurement error or uncertainty [such as standard deviation (SD), standard error (SE) or confidence interval] in addition to the results of hypothesis testing. If the data can be well represented with a graph or figure, these are encouraged if subsequent publication is not anticipated. If numbers and data are not presented due to concerns regarding publication in a refereed journal, indications of relative differences between groups such as odds ratios, % change, and significant differences must be included in the submission to be considered acceptable. In these instances, the authors should submit the data in the form of means, standard deviations, or other descriptions of comparisons among groups in an appendix, which will not be published and only used for review purposes.

Discussion:
Important findings documented in the results of the study should be stated. Results should be related to other work which has been done and how the results differ or agree with previously published work and why any differences may have occurred should be discussed. The practical take home message for the equine practitioner should be clearly defined and stated in the summarizing final statement. This statement may be longer, but should be similar in content to the take home message at the beginning of the paper.

The following items also must be fully explained in the paper: the number of horses that have been worked on, how many will be affected, and evidence that the procedure works and is safe.

Acknowledgments:
Acknowledgments should include financial and material support for research [e.g. Grayson Jockey Club Research Foundation, AQHA Foundation] and technical support for work performed. Authors are expected to disclose the nature of any financial interests (including ownership, employment, consultancy arrangements, or service as an officer or board member) they have with companies that manufacture or sell products that figure prominently in the submission or with companies that manufacture or sell competing products.

Declaration of Ethics:
A Declaration of Ethics statement should be included in the paper under the Acknowledgements section. Authors must declare if they have adhered to the Principles of Veterinary Medical Ethics of the AVMA (https://www.avma.org/KB/Policies/Pages/Principles-of-Veterinary-Medical-Ethics-of-the-AVMA.aspx)

1. If your paper or presentation references the use of a compounded pharmaceutical, please be certain that you are familiar with the FDA guidelines on the use of compounded pharmaceuticals and that the product you reference is in compliance. See section below regarding papers using compounded medications or medical devices.

2. All submissions should cite levels of evidence-based medicine.
You should plan to include any ethical considerations as part of your oral presentation if your paper is accepted.

Conflicts of Interest:
Authors are expected to disclose the nature of any financial interests they have with companies that manufacture or sell products that figure prominently in the submission or with companies that manufacture or sell competing products (this includes ownership, employment, consultancy arrangements, or service as an officer or board member). A Conflict of Interest statement should be included in the paper under the Acknowledgements section whether a conflict exists or not.

Example of COI Statement
Conflict of Interest: Dr. John Doe has no conflict of interest. Dr. Jane Doe has served as a paid technology analyst for the venture capitalists that initiated the formation of Company ABC and served as a member of the Board of Directors of Company ABC from its inception until 2008. Company ABC is currently commercializing the use of Product XYZ. Dr. Jane Doe has also served as a paid consultant and continues to serve on the Company ABC Advisory Board.

All authors are required to disclose any actual or potential conflict of interest including any financial, personal or other relationships with other people or organizations within three years of beginning the submitted work that could inappropriately influence, or be perceived to influence, their work.

At the point of submission, the American Association of Equine Practitioner (AAEP)'s policy requires that authors must disclose and describe the nature of any actual or potential financial and/or personal relationships the author may have. When considering whether a conflicting interest or connection should be declared, the author is asked to answer the following: Is there any arrangement that would embarrass you or any of your co-authors if it was to emerge after publication and you had not declared it?

As an integral part of the online submission process, submitting authors are required to confirm whether they or their co-authors have any actual or potential conflicts of interest to declare, and to provide details of these. It is the Submitting author’s responsibility to ensure that all authors adhere to this policy.

1. Any and all authors listed on the paper must disclose any actual or potential conflicts of interest
2. Any and all authors listed on the paper must disclose if no conflict exists
3. The nature of the conflict (actual or potential) needs to be described

References:
References to published works should be limited to what is relevant and necessary. Number references in the text with superscript numbers consecutively in the order in which they are first cited. Under references, list all authors when there are three or fewer; list only the first three and add “et al.” when there are four or more. The author is responsible for the formatting and accuracy of all reference citations. Since readers frequently depend upon the reference citations to guide them in further reading, it is imperative that the citations are correct so that libraries can locate the papers a reader may wish to obtain.
Examples:

Journal article:


Book:


Chapter in a book:


Proceedings:


Footnotes:

References to dissertations, theses, abstracts, personal communications and papers submitted but not yet accepted for publication should be footnoted:


Bramlage LR. Lexington, KY. (personal communication) 1996.


Products and equipment should be identified by chemical or generic names or descriptions.

All products should be footnoted, along with the manufacturer’s full address. A trade name may be included in a lettered footnote along with the name and location (full mailing address including zip code) of the manufacturer when the product or equipment was essential to the outcome of the experiment or treatment.

Example:

All horses were sedated with a combination of detomidine HCL (10-20 mg/kg IV) and butorphanol tartrate (0.01-0.02 mg/kg IV).

AAEP is dedicated to the humane use of animals in scientific research in accordance with the Institutional Animal Care and Use Committee (IACUC).

IACUC Approval:

AAEP is dedicated to the humane use of animals in scientific research in accordance with the Institutional Animal Care and Use Committee (IACUC).

Compounded Medications or Medical Devices:

To be considered for selection in the Annual Convention program, abstracts that include the use of compounded drugs must adhere to the tenets described in the AAEP Equine Veterinary Compounding Guidelines (2005). Specifically, compounded drug or medical devices cannot be used in lieu of a FDA approved product if the approved product has a label indication for the purpose or condition being evaluated or described in the abstract.

An exception to this policy will be made for abstracts reporting clinical trials conducted in fulfillment of the requirements for the approval of a new drug (FDA) or biologic (USDAs).

Submitted papers that use compounded drugs or medical devices will be reviewed by at least two individuals with expertise in this area selected by the CE Steering Committee. The individuals will then make a recommendation to the EPC about the suitability of the submission for potential inclusion in the program.
Standard of Care:
The AAEP is sensitized to having people use the term “Standard of Care” from the podium. If you plan to do this please include this in your abstract or written submitted material so the EPC can confirm its agreement with your statement.

1. A diagnostic and treatment process that a clinician should follow for a certain type of patient, illness, or clinical circumstance. Adjuvant chemotherapy for lung cancer is “a new standard of care, but not necessarily the only standard of care.” (New England Journal of Medicine, 2004).

2. In legal terms, the level at which the average, prudent provider in a given community would practice. It is how similarly qualified practitioners would have managed the patient’s care under the same or similar circumstances. The medical malpractice plaintiff must establish the appropriate standard of care and demonstrate that the standard of care has been breached.

Deadline:
ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.; under no circumstances will submissions received after the deadline be considered or reviewed. ALL deadlines must be adhered to in order to have the published Proceedings available at the meeting.

Review Process:
To respect the integrity of the Annual Convention program and ensure the fairness of the review process, AAEP has adopted blind reviewing in which the identity of the authors and reviewers are not known to each other. Papers will be reviewed, scored, and selected by the Educational Programs Committee. Please follow the blinding guidelines below.

Blinding Guidelines:
● The title page and/or front matter of the blinded version of a paper should contain no references to any author or to his/her affiliation.
● All unpublished works by an author of the submitted manuscript should be blinded.
● When referring to an author’s publication, the form of third person should be used.
● Any acknowledgments section should be removed from the blinded version. Also, please delete any notes that indicate affiliation, conference presentations, grants, author or departmental web sites, etc.
● Do not use author name or affiliation in the names of the submitted files.

Scoring Criteria:
One goal of the Educational Programs Committee (EPC) in choosing submissions for the AAEP annual meeting is to combine the best available clinical research with clinical experience and expertise to meet the needs of our patients. The AAEP Scoring Criteria can be found at https://aaep2017.abstractcentral.com/.

Pre-Press Approval:
Authors will have final approval at the page proof stage. Changes/updates in numbers, dosages or inappropriate grammar may be made within one week of receiving page proofs. Final grammatical changes will be the decision of the editors. Substantial changes or removal of any data will result in forfeiture of complimentary registration and travel, and exclusion from the program.

Reimbursement:
Presenting authors will receive one complimentary registration and a reimbursement of $550 to help support travel.

Mentors for Authors:
Paper submissions by private practitioners and first time authors are highly encouraged. The AAEP has a list of members in various areas of expertise that have agreed to volunteer their time to mentor an author who needs guidance. To see this list, email Carey Ross at cross@aaep.org.

Scientific Papers: Guidelines for Authors
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017
To submit a paper, go to https://aaep2017.abstractcentral.com/

ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.

Authors who do not intend to publish in a refereed journal are welcome to submit a scientific paper.

Scientific Paper selection will be made by the Educational Programs Committee. The quality of the Scientific Paper will determine the selection. Missing data or proposed, but not completed procedures, will exclude the Scientific Paper or other paper from consideration. AAEP invites information dealing with any subject germane to equine practice, but special consideration will be given to presentations by practitioners and material with practical content or new information. At least one author of a report describing diagnosis, treatment, or the interpretation of medical information should be a veterinarian.

Scientific papers should be formatted as described in the General Instructions for Authors. Scientific papers should be no fewer than 600 words. No upper word limit.

The "How to" Paper: Guidelines for Authors
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017
To submit a paper, go to https://aaep2017.abstractcentral.com/

ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.

“How to” papers are presented to describe and explain a technique or procedure used in equine veterinary medicine or the equine industry. The technique should be relatively new or not widely understood or used in practice. The goal of the “How to” paper is to give the equine veterinarians the information they need to critically evaluate the pros and cons of the technique and implement it in their practice if they choose.

“How to” papers can be patterned after a modification of the style for a Scientific Paper supporting a scientific presentation. Refer to General Instructions for Authors as you prepare your submission. How to papers should be no fewer than 600 words; no upper word limit.
The title should begin with “How to . . . ” and clearly identify the technique or procedure that will be presented. A “Take Home Message” is not required for “How to” papers. The Introduction should include why you use the technique. If there is a problem with the traditional methods or the currently used method can be improved, this should be explained.

The Materials and Methods section should explain exactly how the technique is performed so that another veterinarian familiar with the subject area could follow your example. You may use a step-by-step method for the paper and the presentation. All medications, supplies, and equipment used should be described using generic names. Trade names and addresses of commercial products critical to the technique can be included in footnotes.

The Results section should include a summary of what happens when you use this technique. The number of horses treated in this manner and an assessment of the outcome should be included. You may use personal assertions or data to assert its value, but you must explain how you determined that the technique works.

In the Discussion section you can give your personal views as to why you think the technique works. Discuss the pros and cons of your approach. Explain how the technique has helped you in your practice and why this should be important to your colleagues. The end of the discussion should contain a summary of the technique and its advantages. Case selection, case study number, and case follow-up should all be included.

Review Paper: Guidelines for Authors
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017

To submit a paper, go to https://aaep2017.abstractcentral.com/

ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.

Review papers are presented for the purpose of updating the membership on a new subject or for gathering information that may be conflicting. The aim of the paper is to help the membership put the information in perspective, and to make judgments on conflicting information. A review paper will not principally present original data. The goal is to clarify existing knowledge on a subject and help the membership better use the information in their day to day practice.

Review papers should generally be formatted as described in the General Instructions for Authors except where otherwise noted here. The paper should be titled “Review of Some Subject.” The content of review articles should be organized with headings and subheadings that provide a logical flow to the material presented. A “Take Home Message” is required for a Review Paper. The Introduction should define the subject matter and put it in context, explaining why the review is necessary. The purpose of the review paper should be clearly stated in the Introduction.

Agreement and disagreement within the subject matter should be identified along with the strengths and limitations of the information sources. Reference should be made to the authors who generally support the opinions stated. The author’s perspective, including his/her own interpretation of the information if it is different from previously published opinions, should be included. The end of the discussion should contain a summary and the conclusion that the author has drawn for the audience, based upon the reviewed data.

Abstracts ≤ 250 Words:
Guidelines for Authors
For those who intend to publish in a refereed journal
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017

To submit a paper, go to https://aaep2017.abstractcentral.com/

ALL papers must be submitted as a .pdf online by March 15, 2017, 3:00 p.m. ET.

In order to encourage submission of the newest scientific information for inclusion in the AAEP Annual Convention program and simultaneously not jeopardize future publication of this material in a refereed journal, the following criteria have been developed for these submissions of Scientific Papers that will be published in the AAEP Proceedings. In such instances, the published abstract can be ≤ 250 words. However, these “abbreviated abstracts” should follow a structured format with the same subheadings (Take Home Message, Introduction, Materials & Methods, Results and Discussion) as the full-length scientific paper. Please be aware that the Take Home Message is included in the total word count. The abbreviated abstract does not need references but appropriate acknowledgments should be included. Note that this abbreviated abstract format does not apply to Review, How To, or In-Depth Papers. A full paper conforming to the General Instructions for Authors must also be submitted to allow the reviewers to assess the experimental design, materials and methods, statistical analyses, results (with graphs, tables, charts, etc.) and a discussion of the results as it pertains to interpretation and conclusions (see specific guidelines below for full papers). The submitting author must include a statement that only the short abstract can be published in the AAEP Convention Proceedings. It remains the authors’ responsibility to preserve their right to publish in a refereed journal by contacting the respective journal to discuss their prior-publication criteria, so that an accepted abbreviated abstract will not jeopardize publication in the refereed journal. These submitted abbreviated abstracts should be identified with the words “RESEARCH ABSTRACT” at the end of the title.

Guidelines for Full Papers

- No more than 8 double-spaced pages. This does not include tables, figures, and references
- 12 point font
- 1” margins
- When submitting online, please put both papers in one document; the 250 word abstract should be first, followed by the full-length scientific paper.

A full paper must be included with all 250 word abstracts in order for the abstract to be considered for the program.
Business of Practice Papers:
Guidelines for Authors
63rd AAEP Convention
San Antonio, TX
November 17-21, 2017

To submit a paper, go to
https://aaep2017.abstractcentral.com/

ALL papers must be submitted as a .pdf
online by March 15, 2017, 3:00 p.m. ET.

The general theme for the 2017 Business of Practice Sessions is “Back to Basics.” Several potential topics are listed below, and practitioners with expertise or experience in these areas are encouraged to submit papers to be considered for presentation. Please keep in mind that all submissions must follow the guidelines as outlined below and that accepted. The following topic suggestions are intended to spark ideas that relate to the “Back to Basics” theme. We also welcome paper submissions on any topic pertaining to the Business of Practice.

Potential Topics:
- Reading financial statements, P&L, etc.
- Cash management and cash flow
- Leveraging free resource for business planning (SCORE)
- Compensation basics & options
- Leadership & mentorship
- Client relationships
- Business planning
- Legal structure
- Inventory management

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Guidelines:
Failure to adhere to the following format will result in non-acceptance. It is the author’s responsibility to convince the Educational Programs Committee of the value of the submission, as well as to portray to the reader the contents of the presentation. You may request examples of previously accepted Business papers from cross@aaep.org.

Headings may include (but are not limited to) the following:
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2. Introduction
3. Solution
4. Results
5. Discussion
6. Acknowledgments
   i. Declaration of Ethics
   ii. Conflicts of Interest
7. References

Title:
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A description of a single or numerous business solutions are explained in detail.

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Barbara Dallap Schaer, VMD, DACVS, DACVECC

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1. Introduction

Despite many advances during the last 40 years regarding colic surgery, there is no doubt the mere word “colic” strikes fear into the hearts of horse owners. The earliest studies in the 1960s reported an abysmal prognosis for colic, and survival rates for surgical colic described in the late 1980s ranged from 39 to 58%.1,2 In these early retrospective studies, postoperative complications included life-threatening peritonitis and anastomotic failure, as well as complete incisional dehiscence, problems that are much less common today. Historically, a poor prognosis for surgical colic was likely due to delayed referral, protracted or delayed diagnosis and intervention, and less experience with surgical technique. It seems that in the mind of many owners, colic surgery is still strongly associated with a poor prognosis. In addition, many owners are concerned that their horse will no longer be a useful athlete if they have had colic surgery. Owners are then reluctant to incur significant financial burden with an uncertain outcome.

Today the reported prognosis for the treatment of colic has greatly improved. Recent studies cite vastly improved survival for some of the more challenging surgical lesions, from large colon resection3 to gastrojejunostomy.4 Survival to discharge for horses recovering from colic surgery at our institution is 90.8%.5 Although improved outcome is associated with advanced surgical techniques and better monitoring of the critically ill equine patient, perhaps timely referral and rapid diagnosis and intervention plays the biggest role in survival. A complete, thorough, and timely workup of the horse in acute abdominal discomfort has the greatest effect on successfully treating colic. Appropriately setting client expectations and developing a shared agenda for treatment with the owner should greatly improve their understanding and satisfaction in a difficult and stressful situation.

2. Initial Evaluation and Stabilization

Careful collection of a complete history, including an accurate signalment, information regarding management practices, and recent administration of medications, can be extremely useful in narrowing the possible causes of abdominal discomfort. The diagnostic steps that comprise a colic workup are fairly standard—perhaps what varies is how many of them are needed to make a diagnosis, and what components are reasonable or practical to complete in a field vs referral setting. A recent prospective study in the United Kingdom evaluating the assess-
ment of 1016 colic patients by veterinary practitioners reported that 76.4% were noncritical, meaning they were managed with minimal medical treatment. The challenge becomes identifying the remaining roughly 25% that require intensive medical management, surgery, or euthanasia. Standard components of colic triage should include a brief physical examination/rapid patient assessment, abdominal palpation per rectum, passage of a nasogastric tube, and actively checking for reflux. Ancillary diagnostic tests can include ultrasonography and abdominocentesis. Perhaps the most useful hematologic parameters are packed cell volume, total solids, and serum lactate.

3. Physical Exam/Rapid Patient Assessment
A rapid patient assessment is essential to determining whether a horse with colic will require referral/intensive management or be able to be managed in the farm setting. The assessment should focus on severity and nature of pain, mucous membrane (and scleral) color, pulse quality, jugular refill time, degree of abdominal distension, heart rate, respiratory rate, and rectal temperature. Careful observation of how the horse displays what the owner/trainer has perceived as “colic pain” can also be very useful. A gastrointestinal cause of abdominal pain is often assumed in horses that present with varying signs of discomfort. However, there are several diseases that can take on the clinical appearance of colic, but are not colic.

4. Abdominal Palpation per Rectum
Despite advances in ultrasonography, abdominal palpation per rectum remains a mainstay of the colic workup. In the prospective study of 1016 horses, abdominal palpation was performed in 73.8% of horses. A careful but systematic approach to the rectal examination is extremely useful, and should not be omitted from the process. It probably makes the most sense for each practitioner to develop his or her own approach, but the approach should be consistent. Specific palpation goals might include the base of the cecum, positioning of the colon, cranial palpation directed on either side of the root of the mesentery, spleen, nephrosplenic space, small colon, bladder, and ovaries and uterus if applicable. Satisfied findings can be simply categorized as large bowel distension, small intestinal distension, or impaction (large colon, small colon or cecum). In the case of a large bowel impaction, it is important to attempt to determine whether the viscus involved is cecum or colon. In most cases, the cecum can be identified by tracing the base of the viscus to a relatively distinct attachment to the dorsal body wall, a feature lacking in the palpation of the large colon per rectum. Typically, palpation of a large colon impaction can be identified by its relatively caudal position in the abdomen (often pelvic inlet), the fact that one can readily sweep dorsally over the body of the large colon without encountering any dorsal body wall attachment, and the cecum can still be palpated to the right of the affected viscus. This distinction affects patient management, and could play a significant role in determining prognosis and treatment plan. If large bowel distension is appreciated, one should attempt to characterize the positioning of the colon. Other meaningful findings that could suggest an immediate need for surgery are the palpation of significantly thickened small bowel, or an intussusception.

A change in clinical signs or level of discomfort is an indication to repeat abdominal palpation per rectum. The ability to appreciate an abnormality on palpation per rectum can change in a matter of an hour, and repeat palpation is an often overlooked, but very useful tool in the horse that is not improving or has had a change in clinical status.

5. Nasogastric Intubation/Checking for Reflux
Passing a nasogastric tube and actively checking for reflux is an essential component of the colic workup. Probably the most commonly made mistake is the failure to create an effective siphon to aid in the evacuation of the stomach contents, in combination with a lack of persistence. Placement of the tube into the stomach is not sufficient to determine the presence or absence of reflux; most horses will not spontaneously reflux, regardless of the amount of reflux present. A siphon can be created by introducing a solid column of water into the tube to the level of the stomach, using either a stomach pump or half-liter dose syringe. The tube is then lowered, and the column of water, now contiguous with the stomach contents, will readily follow gravity and flow of the stomach. If small intestinal distension is palpable on abdominal palpation per rectum, do not administer any fluids via nasogastric tube.

6. Initial Patient Stabilization
Typically, patient stabilization is occurring simultaneously throughout the evaluation process. Initial treatment of a horse with colic often includes administration of analgesic/anti-inflammatory medication, most commonly flunixin meglumine (1.1 mg/kg IV). Additional options are firocoxib (2 mL/1000 lbs IV only, or 0.1 mg/kg orally) or phenylbutazone (2.2 mg/kg IV). Depending on the circumstances, treating the horse with N-butylscopolammonium bromidea (0.3 mg/kg IV) might be helpful. Buscopan competitively inhibits parasympathetic activation (via muscarinic receptors) of smooth muscle cells, resulting in an antispasmodic effect. It is important to remember that N-butylscopolammonium bromide can increase the heart rate for up to 30 minutes following administration; during this time frame, heart rate may not be reflective of discomfort or declining physiologic status. The use of alpha-2 agonists in combination with butorphanol (0.1–0.01 mg/kg IV) to control discomfort during the completion of the examination is very common, with xylazine (0.2–1.1 mg/kg IV) and detomidine (10–40 μg/kg IV being the most frequently
used medications. It is important to realize that the onset of action of detomidine is appreciably slower than xylazine, a point that is not insignificant if you have a relatively violent patient. It is not unusual for a clinician to administer repeated doses of detomidine in a relatively short time frame, impatiently wondering why the horse’s comfort level has not improved. Adverse effects might include profound bradycardia or collapse, so use caution. A larger dose of xylazine in combination with butorphanol might be more effective, depending on the patient.

If indicated, fluid volume resuscitation is often ongoing during a colic workup in a referral hospital, and is often possible in a field setting depending on the circumstances. A common approach is to begin with a 20–30 mL/kg bolus of polyionic, pH-balanced crystalloids followed by repeat patient reassessment (heart rate, pulse quality, jugular refill time, capillary refill time, limb temperature, packed cell volume/total solids/lactate if available). Ongoing losses or circumstances affecting cardiovascular stability, such as presence of reflux or endotoxemia due to large colon volvulus, will influence the need for further fluid volume resuscitation. Rapid intravascular volume expansion can be temporarily achieved with a 4-mL/kg dose of 7.2% hypertonic saline, but this effect will be transient, and must be followed with appropriate volume replacement. An additional benefit of the administration of hypertonic saline is the improvement of vascular tone, believed to be mediated by the release of vasopressin.

Depending on the circumstances, enteral fluid therapy can be a very effective way of correcting mild hypovolemia in the acute colic patient, particularly in horses with large or small colon impaction. In patients without significant dehydration, enteral fluid alone may be completely effective in improving hydration and aid in treating the impaction. What to administer via nasogastric tube is strongly linked to practitioner/clinician preference (water, mineral oil, electrolytes, etc.). Studies have demonstrated that aggressive enteral fluid therapy using balanced isotonic electrolyte solution is the most effective choice for resolving large colon impaction while avoiding relevant electrolyte disturbances.7,8

7. Additional Diagnostic Tests

Ultrasoundography

The use of ultrasound in horses with colic is well described, and is certainly helpful in both a field and referral setting. Many clinicians at tertiary care referral practices consider a brief sonographic examination of the horse with acute colic standard of care. The sonographic appearance of lesions causing colic in the horse are well described in the literature.9 A limited, rapid scan is commonly used in human patients presenting to emergency departments for acute abdominal pain or trauma, and a similar approach has been described in dogs10 and horses.11 In horses, the identification of small-intestinal lesions are identified sonographically with relatively good sensitivity and specificity.11 A recent prospective clinical trial in our hospital evaluated the usefulness of a modified fast, localized abdominal sonography in the horse (mFLASH) in horses with acute colic, in combination with abdominal palpation per rectum.12 The mFLASH (Fig. 1) consists of five sonographic windows instead of seven,11 and is specifically aimed at detecting surgical lesions.12 Agreement between diagnostic modality and lesion localization (large bowel vs small bowel) was better with mFLASH than transrectal palpation alone, and mFLASH was more sensitive and specific for identifying strangulating small-intestinal lesions.12 Obviously, ultrasonographic examination can also be useful in patients who are too small for safe abdominal palpation per rectum (foals, small weanlings, Miniature Horses).

Abdominocentesis

Evaluation of peritoneal fluid has been a relatively consistent component of the colic workup, although it is probably most commonly used in a referral setting. Abdominocentesis is particularly useful in confirming strangulating small intestinal lesions, gastrointestinal rupture, peritonitis, and possibly hemoabdomen. The presence-compromised bowel is typically associated with serosanguinous-peritoneal fluid, increased nucleated cell count (>5000 cells/μL) in combination with increased total solids (>2.0 gm/dL), or increased lactate (compare with...
serum lactate). The increased reliance on peritoneal lactate has likely decreased the absolute need for availability of a hematology analyzer for peritoneal analysis. If the peritoneal lactate is greater than the peripheral lactate, one can usually feel fairly confident that some degree of bowel compromise is present. The difference in peritoneal: plasma lactate can vary depending on the clinical condition; but in cases of strangulating intestinal lesions, the peritoneal lactate is often 2–4 times that of the peripheral lactate. In the prospective study by Latson et al, horses with strangulated small intestine had a lactate value of 8.45 mmol/L, compared with those with nonstrangulating obstruction 2.09 mmol/L.

Although the usefulness of peritoneal fluid in the evaluation of the horse with acute colic has been well documented in the literature, it is important to remember that it can be associated with a few significant complications, such as enterocentesis (sometimes innocuous, sometimes not), or full-thickness laceration of bowel or spleen. Some clinicians feel strongly that the use of a teat cannula decreases the risk of complication. We have seen complications associated with all methods of abdominoceotomy. As with any diagnostic procedure, it is important to consider the risks vs the benefits of the proposed intervention.

8. When to Refer/Indicators for Surgery
The fastest referrals, and indeed the shortest work-ups, are associated with the violently painful horse presenting for colic. Unrelenting discomfort that cannot be managed medically usually results in a relatively rapid progression to surgical intervention or euthanasia. Other indicators for referral might include moderate or severe hypovolemia, large amounts of gastrointestinal reflux, signs of physiologic decline (increased heart rate, respiratory rate, increased lactate, abnormal mucous membrane color), or discomfort that persists despite administration of analgesics, even if it is not violent. In some cases, the signalment in combination with the presenting clinical signs might influence the decision to refer; a 25-year-old gelding with a heart rate of 56 bpm and mild abdominal discomfort is much more concerning than a yearling with the same clinical findings. It is also important to distinguish between cecal and large colon impaction, as one might be more inclined to refer a horse with cecal impaction, depending on the owner’s feelings regarding surgery.

The decision for surgery is based on the compilation of all components of the colic workup. Abnormal findings on abdominal palpation per rectum, such as thickened small intestine or palpable intussusception, and peritoneal fluid that is serosanguinous or has an increased lactate, are often indicators that surgery is required. Horses that fail to respond to medical management, despite aggressive intervention, and do not have salient evidence of enterocolitis, might need an exploratory celiotomy to make a diagnosis. Surgery should at least be considered, and discussed with the owners, in horses with cecal impaction/dysfunction, given that it is difficult to predict which will develop a cecal rupture. It is important to remember that timely referral, thorough evaluation, and appropriately timed surgical intervention have likely been the greatest contributors to the improved prognosis for colic appreciated in the last 10 years.

9. When It’s Not Colic
One of the few areas in our hospital setting in which initial patient assessment approaches a protocol is the admission and workup of a colic patient. All members of our clinical team have been trained in the elements of the routine of “colic workup,” which we have reiterated in lectures, rounds, and talks. In many settings, and in fact in the case of most horses presenting with colic, adherence to a protocol can be quite useful. However, horses may demonstrate colic-like behavior and have a disease that is not of gastrointestinal origin, with specific etiologies varying based on geographic location and equine population. Occasionally these patients are interpreted as “uncomfortable” or “painful” enough to warrant exploratory celiotomy; in some cases this could be contraindicated. Misdiagnosis or delay in treatment could negatively affect outcome.

Common causes of “colic” behavior that is not associated with malposition of gastrointestinal tract can include problems of neuromuscular, reproductive, metabolic, or respiratory origin. Horses with rabies, exertional rhabdomyolysis, botulism, tetanus, uterine artery rupture, hyperammonemia, and pheochromocytoma have all been presented for colic to our hospital. Careful attention to the history and details of the initial assessment by the referring veterinarian, as well as the description of the first signs observed by the owner, can be extremely useful in determining the cause of the clinical signs. Horses suffering from various toxicities can also display signs that can be interpreted as colic, such as jimson weed toxicosis, ingestion of Acer rubrum (red maple leaf), cantharadin toxicity, or adverse phenazine reaction. It is safe to say that few of these patients would benefit from inadvertent exploratory celiotomy, and a delay in treatment could certainly decrease chances of survival.

10. Conclusion
The referring veterinarian plays a critical role in the initial evaluation and referral of the horse with colic. Increased awareness and timely referral both play an extremely important role in improving the survival of horses that require surgery. A thorough workup and appropriate compilation of all the available information is important for all veterinarians evaluating horses with colic, in either a primary or referral setting. It is also important to remember that there are a variety of colic “imitators” that
require careful observation and integration of all information to avoid inappropriate intervention or delay in treatment.

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**Declaration of Ethics**
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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Review of How to Triage a Dystocia

Michael A. Spirito, DVM

1. Introduction

Dystocia is defined as difficult parturition to the point of human intervention. It can be due to a variety of factors including fetal, maternal, a combination of the two, or iatrogenic. In a study by Frazer et al in 1997,1 the most common breeds to experience dystocia are Thoroughbreds, Standardbreds, and Draft breeds. One of the most important parts of the initial workup of a dystocia is to determine that the cause of the mare's distress is due to foaling. Therefore, understanding the stages of parturition and what is normal is important.

Stage I labor is composed of the mare showing signs of abdominal discomfort as the foal moves into the correct orientation. Proper space orientation includes presentation, position, and posture. Presentation should be anterior longitudinal with the foal's head presented toward the mare's vulva. Normal position is dorsal sacral describing the relationship between the foal's back with the mare's spine. Proper posture is extension of the extremities, head, and neck (Fig. 1a).

Stage II labor begins with the rupture of the chorionallantois and is completed when the foal is expelled. This stage should be no longer than 30 minutes and when decision to refer to a clinic or continue attempting to reduce the dystocia is the most important. Stage III labor is complete with passage of the placenta.

2. Dystocia–Triage

Obtaining a comprehensive history is key to initial decision making. When called for a dystocia, key questions that should be asked include the following:

1. How old is the mare?
2. Is this the first foal?
3. Is the foal to term and has the mare bagged up?
4. When did she begin to foal or break water?
5. Have you seen or felt the foal move?
6. Who owns the mare and are they aware of the situation? Will they want a C-section if required?

Depending on the information provided, several decisions can be made prior to the initial examination of the horse. Information regarding the viability of the foal and positioning of the foal, can be acquired prior to arriving at the farm or seeing the mare at the clinic. Financial constraints imposed by the owner can help determine whether the dystocia can be relieved at the farm or if immediate referral to a nearby clinic is warranted. To improve fetal viability, having the information needed to make decisions quickly is crucial. Time is of the essence in dealing with a dystocia—10 minutes...
can be the difference between an excellent result and a dead foal.

When you arrive at the farm or the mare arrives at your clinic, a physical examination of the mare can be performed. Depending on the mare’s comfort and strength of contractions, sedation with xylazine or xylazine and torbugesic can aid in the examination. The perineum should be quickly rinsed with iodine to maintain hygiene and a vaginal examination performed to assess the foal’s position. Once the orientation of the foal is identified, a decision can be made as to the next step in reducing the dystocia.

3. Procedures to Solve a Dystocia

There are four procedures that can be used to reduce a dystocia. Attempt should be made to deliver the foal via assisted vaginal delivery first. The method can be used at both the farm or referral clinic. Manual manipulation of the foal to correct malposition can be performed standing with the mare sedated. The use of tools such as a head snare or chains on the distal limbs is useful to assist the mare to deliver the foal. Care should be taken when pulling on the chains to pull in time with the uterine contractions to reduce trauma to the mare and foal. Once the rib cage enters the pelvic canal, the mare should be allowed to finish delivery herself to prevent rib fractures.

Controlled vaginal delivery is when the mare is induced under general anesthesia and placed in Trendelenburg position with the hind limbs lifted via a hoist. The position is useful to facilitate manipulation of the foal in the uterus by the use of gravity to repel the foal. Controlled vaginal delivery is useful for delivery of live or dead foals and in combination with a fetotomy. The advantages of the procedure are obvious in that the foal can be manipulated without pressure from the mare and the foal can be pushed in to allow much more room for manipulation. Generally, this method is performed at a referral clinic due to the equipment needed for general anesthesia and to elevate the hind end of the mare.

Cesarean section (C-section) is indicated for dystocia that cannot be corrected vaginally. C-section is performed with the mare in dorsal recumbency with a caudal ventral midline incision. Indications for this procedure include severely malpositioned fetuses, abnormal birth canal, or to decrease reproductive tract trauma. Although there are many complications that can arise with a C-section, mares that underwent the surgery had an 80–85% discharge rate from the hospital in a study performed by Freeman et al in 1999.2 In addition, a study by Byron et al in 20023 showed 59% of mares undergoing C-section had a live foal 1 year post-operatively. Another study by Abernathy-Young et al in 20124 showed that breeding in the same year as C-section, a dystocia for ≥ 90 minutes before C-section, and mare age ≥ 16 years were associated with poor foaling rates. Prognosis for delivery of a live foal in years following C-section...
was good if duration of dystocia was less than 90 minutes and the mare was less than 16 years old at the time of surgery.

Fetotomy is reserved for dystocia when the foal is confirmed dead and vaginal manipulation does not result in successful delivery of the foal. Fetotomy should be performed by experienced personnel. The complications with a fetotomy are potential laceration of the uterus either with the fetotomy wire or the sharp ends of a bone. For example, when the head and neck are resected a hand should be placed on the remaining vertebrae and held there during the extraction of the remaining fetus.

4. Most Common Presentations

Most Common Anterior Presentations

Incomplete Elbow Extension

At the incomplete elbow extension position, fetal hooves lie at the same level as the muzzle (Fig. 2). The procedure to correct this is to repel the fetal trunk as far as possible and then apply traction on one limb at a time, thereby introducing the foal in a more normal position. The foal’s head should then be pulled into and through the birth canal and at this time the foal may be pulled with gentle traction.

Dog Sitting/Hurdling Position

In a dog sitting/hurdling position (Fig. 3) your first clue that something is wrong will be the apparent normal position of the foal that seemingly will not move. Upon further palpation, you will find one or two hind feet up. The mare should be placed in the Trendelenburg position. This is a very critical situation and should be handled with utmost caution. It is occasionally possible to push the foal back into the uterus far enough to allow for one or both of the hind legs to be positioned cranial to the pelvic brim (Fig. 4). If you manage to do this then the foal can be pulled. If this maneuver is unsuccessful you should move to a C-section.

Carpal Flexion/Contracture

Carpal flexion/contracture (Fig. 5) is a very common
presentation and these foals are generally either quite large or contracted to some extent. These can be either unilateral or bi-lateral. They can be reduced in the standing mare. It is important to be able to reach the pastern to place a chain around it. If you cannot reach the pastern, then the mare should be placed in the Trendelenburg position and the foal repelled to some extent to create some working room. The chain is then applied to the pastern, and the carpus is reflected laterally. A hand should guide the foot and the rotation should be gradual so as to not tear the uterus.

**Foot Over Nape Position**

Foot over nape position (Fig. 6) is when one or both of the forelimbs is displaced over the head and against the roof of the vagina. Correction is accomplished by repelling the fetus and forelimbs are pulled under head. If this is not corrected immediately, there is a high risk of rectovaginal fistula or a third-degree perineal laceration.

**Head and Neck Lateral Flexion**

Head and neck flexion (Fig. 7) is a common abnormality, and difficult to correct. If the fetus is alive, an attempt should be made to repel the foal and bring the head around. Placement of a snare allows traction on the head while the body is repelled. If the foal is dead, a fetotomy at the level of the base neck is a good solution. You must be careful to guide the remainder of the neck through the birth canal so as to not lacerate the roof of the vagina.

**Head and Neck Ventral Flexion**

Ventral deviation can be relatively easy to correct if the fetal nose is just below the brim of the pelvis and the foal is not too large. Pressure is applied to the poll and the snare can be placed on the lower jaw. In severe cases, the neck is tucked down between the two legs and you may be unable to reach the head (Fig. 8). If this is the case, you may need to perform a C-section.

**Shoulder Flexion**

This presentation may be unilateral (swimming posture, Fig. 9), or bilateral (diving posture.) The fetal head may make access to the retained forelimb impossible. If this is the case, a C-section may be the only viable option.

**Most Common Posterior Presentations**

Common posterior presentations are generally referred to the facility almost immediately. These are extremely difficult to correct under field conditions.

**Hock Flexion**

Hock flexions (Fig. 10) represent approximately 25% of the referred posterior cases. These are typically bilateral, and you run the risk of rupture of the dorsal wall of the uterus if you attempt to pull the foal. If the foal is small enough and there is adequate room, you can attempt reduction. Otherwise, you should progress to a C-section if the foal is alive and fetotomy if the foal is dead.
Bilateral Hip Flexion (Breech)
Bilateral hip flexions (Fig. 11) are generally associated with deformed foals. It is unlikely that manual reduction will be successful in these cases, and C-section is generally preferred.

Most Common Ventral Presentations

Anterior Presentation, Ventral Position
These are generally easy to reduce, and can usually be resolved at the farm. It is important to keep the head straight while rotating the foal and engaging it into the birth canal (Fig. 12).

Posterior Presentation, Ventral Position, Extended Posture
There is a risk that the hind legs penetrate the vagina or the rectum with this presentation (Fig. 13). An attempt can be made to rotate the foal and deliver in a posterior manner. This will be a reasonable approach as long as the foal is not overly large, in which case there is risk of rupture of the gastrocnemius muscle at its femoral attachment.

Transverse Presentations
These transverse presentations (Figs. 14 and 15) are not common, and are most often associated with a congenital abnormality. The majority of them are ventral. It is important to make sure you are not dealing with twins, which can usually be resolved without a C-section; otherwise, most of these should go to surgery or be resolved with fetotomy.

5. C-Section
There are many instances in the author’s practice in which C-sections are an elective procedure. This is usually due to a pre-existing condition such as a damaged cervix or a mare with a deformed pelvis. There are several fetal presentations that will generally go almost immediately to C-section. Breech presentations are almost impossible to reduce and are generally deformed foals. Transverse presentations are generally dead foals or...
severely deformed. Hind feet presented, these can often be viable foals and can occasionally be pulled backward but if too much traction is applied you can get a rupture of the gastroc or the peroneus tertius, neither of which the practitioner wants to explain to the client or treat. If they can come out fairly easily and the owner does not want a C-section, then give it a try. Otherwise, go with a C-section. If the head and neck are both back and all you can feel is the back of the neck and the two front feet, you can try and reduce if it is a small foal; otherwise, fetotomy of the head and neck is required for a vaginal delivery or a C-section is necessary. In this position with the head and neck all the way back it is quite difficult to tell whether the fetus is alive. If the foal is valuable, perform a C-section. It is important not to linger with uncertainty in dealing with these problems. It is very easy to spend 15–20 minutes trying to reduce a dystocia and this is valuable time for several reasons: the obvious one is the viability of the fetus, but also fatigue and swelling of the birth canal in the mare should be considered. The longer the events take, the higher the probability will be that the mare may not survive. Obturator paralysis is directly linked to duration of the dystocia and fetus positioning. If a mare goes down on the way to the clinic and is recumbent on presentation to the clinic, her chances of survival diminish substantially.

We make a point to try and determine early in the process whether a C-section is going to be required. On maiden mares that are not bagged up or have not relaxed sufficiently, and are term with a large foal, the author will generally make the “Big Foal/Small Hole” call and move to a C-section in quick order after an attempt to reduce the dystocia by putting the mare in the Trendelenburg position and attempting to pull the foal. This asymmetry between the size of the birth canal and the size of the foal should be kept in mind, especially if the mare is overdue or is not bagged up and has not relaxed in her vulva.

6. Fetotomy

Fetotomy should be performed by experienced personnel. The problems with a fetotomy are potential laceration of the uterus either with the fetotomy or by sharp ends of a bone. For example, when the hind leg is removed, a sharp end of the femur can easily lacerate the uterus. Fetotomy is a very valuable tool and should be used with caution when necessary. When initiating a fetotomy, you should

Fig. 11. Bilateral hip flexion.

Fig. 12. Anterior presentation, ventral position.

Fig. 13. Posterior presentation, ventral position, extended posture.
have a plan before you begin and the sections should be removed at specific anatomical locations. The head and neck should be removed at the base of the neck and not in the middle. The pelvis should be split as close to midline as possible. If fetotomy is performed in a judicious, cautious manner, then the mare will have a productive life. If not, she may be significantly damaged.

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Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

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References and Footnote


Diagnosis, Management, and Triage of Respiratory Emergencies

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1. Introduction
Respiratory disease constitutes a major cause of morbidity and mortality in horses. Timely diagnosis and or referral to provide optimal therapeutic intervention is critical to the outcome of these cases. The objective of this article is to outline the approach to the diagnosis, treatment, and management of a select few respiratory conditions in the field, including when referral for tertiary care should be initiated.

Clinical manifestation of respiratory distress may or may not be obvious depending on the rate of onset of the condition and its severity. Disease processes with an acute onset will typically exhibit signs of respiratory embarrassment. Nostril flare, tachypnea, usually with an increased abdominal component to expiration, may be present. Short shallow breaths may accompany the tachypnea. Horses may also exhibit a cough or nasal discharge, and varying degrees of exercise intolerance. Horses with a pleural component to the disease process may exhibit reluctance to walk due to pleural pain or pleurodynia. Horses with this condition may also stand with their elbows abducted, an effort to remove external pressure on the thoracic wall. This clinical manifestation can often be misconstrued as a sign of colic or laminitis.

Initial examination should begin with assessment of the mucous membranes. Cyanosis may reflect the presence of hypoxemia and the need for oxygen supplementation. Injection or hyperemia of mucous membranes may reflect an infectious disease component. Careful auscultation of the trachea and lung fields should be performed. Although auscultation of the respiratory tract in the adult horse necessitates the use of a rebreathing bag, its use may not be necessary in the patient with respiratory embarrassment because it will likely exacerbate the existing distressed state. Auscultation of the trachea may reveal the presence of a tracheal rattle, the degree of which reflects the quantity and viscosity of any mucus present. Thicker more viscous mucus may not elicit a tracheal rattle. Lung auscultation may determine patency of the lower airways and the presence of any adventitial lung sounds such as crackles or wheezes. Both lung fields should be auscultated in their entirety. This author prefers to begin auscultation in the cranial dorsal lung field, and move ventrally toward the most dependent portions of lung. This increases the chance of detecting regional decreases in bronchovesicular lung sounds, which most often occur in the compromised ventral lung fields in most respiratory conditions. Pleural friction rubs may be
present in the acute stages of the disease process. Cardiac sounds may radiate over a wider area due to the presence of consolidated lung. Percussion of the thoracic body wall may also be employed to detect the presence of a fluid line.

Thoracic ultrasound is the most valuable diagnostic procedure used in the diagnosis and management of lower respiratory tract disease. It allows for critical evaluation of the pleural space and lung parenchyma. Ideally a 2.5–5-MHz curvilinear probe with a maximum depth of 30 cm should be used to thoroughly assess the thoracic cavity, cranial mediastinum, and lungs. However, use of a linear probe of higher frequency may be sufficient to provide useful diagnostic information. Beginning once again in the cranial dorsal lung field and moving ventrally within the confines of the intercostal rib spaces, the pleural surface can be assessed for any breaches in its integrity, which may range from mild pleural roughening to areas of consolidated lung involving the pleural surface (Fig. 1). The presence of free fluid or pleural effusion within the thoracic cavity should be determined, being sure to evaluate the cranial-ventral-most aspect of the thoracic cavity. Pleural effusion appears as anechoic fluid between the parietal and visceral pleural surfaces. The cellularity of the fluid present will dictate the level of echogenicity of the fluid. When evaluating the dorsal lung field, care should be taken to observe for contact and movement of the visceral pleural surface against the parietal pleura. Lack of movement of the lung surface in these regions may reveal the presence of free air in the thoracic cavity, and thus a component of pneumothorax. The presence of intrathoracic fat and pleural folds in the cranioventral thorax can sometimes be mistaken for pathologic abnormalities. Intrathoracic fat is located in the cranial-ventral-most aspect of either hemithorax adjacent to the pericardium. It typically has a smooth rounded border and is of moderate echogenicity.

2. Bacterial Pleuropneumonia

Pleuropneumonia is a severe form of pneumonia characterized by the presence of inflammation of the visceral and parietal pleural membranes with subsequent transudate production and sequestration of fluid into the thoracic cavity.

Most cases of pleural effusion and pleuritis occur secondary to bacterial pneumonia. Other potential causes of pleural effusion include fungal pneumonia, hemothorax, and forms of neoplasia such as mesothelioma and mediastinal lymphoma. Determining when pleural effusion may be present in a lower respiratory tract disease process, or when pleural drainage may be warranted can sometimes be difficult to ascertain.

3. Epidemiology

Racehorses seem to be at greatest risk of developing bacterial pleuropneumonia. Upper respiratory tract viral infections, as well as stressful events such as long-distance transportation and racing may all contribute to development of disease in any breed. General anesthesia, immunosuppressive therapy, and poor nutritional status may also lead to compromise of the respiratory defense mechanisms. These stressful events may alter the host’s respiratory defense mechanisms such as suppression of phagocytic activity. Bacterial pleuropneumonia secondary to aspiration of feed material associated with esophageal obstruction is also seen in a host of other breeds. Exercise-induced pulmonary hemorrhage may also predispose the development of pneumonia.

4. Pathogenesis

Suppression of the pulmonary defense mechanisms permits bacterial contamination of the lower respiratory tract to progress to pneumonia. Most bacteria associated with pleuropneumonia are ubiquitous in the horse’s environment, and become pathogenic when pulmonary defense mechanisms are altered. The most common aerobic bacterial isolate is *Streptococcus equi subsp. zooepidemicus*. Gram-negative bacteria such as *Klebsiella pneumoniae*, *E. coli*, *Actinobacillus*, and *Enterobacter* spp. are also often isolated, along with anaerobic bacteria such as bacteroides and fusobacterium species. Horses subjected to long transport distances and that are unable to lower their heads to clear their airways are at great risk of bacterial contamination of the lower respiratory tract. Significant bacterial contamination of the lower respiratory tract may also occur during dirt racing under wet conditions. Pulmonary hemorrhage associated with racing may also be a predisposing factor in the development of bacterial pneumonia.
5. Clinical Examination

Clinical signs vary with the stage of the disease process and the degree of effusion present. Acutely, most horses are febrile, anorectic, and or lethargic. They may exhibit a cough or nasal discharge, exercise intolerance, and some degree of respiratory effort as evidenced by nostril flaring or an abdominal component to expiration. Pleural pain or pleurodynia may be evident upon deep palpation of the intercostal space. Pleurodynia may also be manifested as a reluctance to move, abducted elbows, or stiff forelimb gait, and may be mistaken for laminitis or exertional rhabomyolysis. Rapid weight loss may occur in chronically affected horses. The development of sternal and distal limb edema may be present in advanced cases.

6. Diagnosis

Diagnosis of the condition is based upon historical information gathered in addition to clinical and diagnostic findings. Thoracic auscultation with the aid of a rebreathing bag typically reveals diminished or absent bronchovesicular lung sounds in the mid to cranioventral lungs fields. Pleural friction rubs may be present in the acute stages of the disease process. Cardiac sounds may radiate over a wider area due to the presence of consolidated lung. A tracheal rattle is often auscultated indicating exudate in the trachea. Percussion of the thoracic body wall may also be employed to detect the presence of a fluid line.

Bloodwork typically reflects evidence of nonspecific inflammation or infection. In peracute cases a leukopenia may be noted. Hyperfibrinogenemia is usually present. Serum amyloid A (SAA) is typically significantly elevated given the degree of bacterial involvement. In more chronic cases leukocytosis may be observed along with anemia of chronic inflammation and a low albumin-to-globulin ratio.

Thoracic ultrasound is the most valuable diagnostic procedure used in the diagnosis and management of this condition. It allows for critical evaluation of the pleural space and lung parenchyma. The quantity and character of the pleural fluid along with the degree of the fibrinous component can be assessed. Pleural effusion appears as anechoic fluid between the parietal and visceral pleural surfaces (Fig. 2). The character of the fluid depends on the degree of cellular infiltrate. Strands of fibrin may be seen floating throughout the fluid, and adhered to the lung, diaphragm, or thoracic wall (Fig. 3). The pericardial diaphragmatic ligament should not be mistaken for fibrin. Consolidated lung appears as areas of hypoechoic tissue (Fig. 2). It is often observed floating within the free pleural fluid (Fig. 2). Bright gas echoes may appear within the consolidated lung tissue and reflect an anaerobic bacterial component or the presence of a broncho-pleural fistula (Fig. 4). A mid-to-cranioventral distribution of affected lung tissue is most common.
Thoracic radiographs are useful only after the pleural fluid has been drained, given that the fluid line will prevent proper imaging of the affected lung. Endoscopic examination should be performed to assess for any upper respiratory tract abnormalities such as dysphagia, which may have contributed to the development of the pneumonia. The quantity and character of the exudate in the trachea may also be briefly assessed prior to sampling.

Transthecal wash samples should be collected and submitted for cytological analysis as well as aerobic and anaerobic bacterial culture. Pleural fluid obtained via thoracocentesis should be submitted for cytology and aerobic and anaerobic bacterial culture. In affected horses the fluid may be turbid with a sanguineous component. The presence of foam reflects the presence of large quantities of protein in the fluid. A malodorous component suggests the presence of anaerobic bacteria. Decreased pleural fluid glucose concentrations (<40 mg/dL) and pleural fluid lactate concentrations greater than a concurrent plasma lactate concentration may suggest a septic effusion.

### 7. Treatment

**Antibiotic Therapy**

Broad-spectrum antibiotic therapy should be used pending culture and sensitivity results. A common initial choice would be a form of penicillin in combination with either an aminoglycoside (gentamicin) or fluoroquinolone (enrofloxacin). Metronidazole should also be added to provide additional anaerobic coverage, given that penicillin is ineffective against *Bacteroides* spp. A 6–8-week course of antibiotic therapy is usually warranted depending on the severity of disease. Ideally a 10–14-day course of intravenous antibiotic therapy should be used prior to switching to an oral antibiotic regimen. Chloramphenicol administered at a dose of 50 mg/kg orally four times a day is this clinician’s preferred choice of oral antibiotic depending on susceptibility results. Response to therapy is assessed by serial ultrasonographic evaluation, the presence of continued fevers, and resolution of bloodwork abnormalities such as SAA.

This clinician also employs the use of nebulization of antibiotics as an adjunct to systemic antibiotic therapy in these cases. Ceftiofur is most often used at a dose of 2.2 mg/kg once a day due to its effectiveness against *S. zooepidemicus*.†

**Pleural Drainage**

Drainage of pleural effusion is critical in allowing for the re-expansion of the lungs. Horses may present in varying degrees of respiratory embarrassment. As a general rule, if there is enough fluid to facilitate floating of the consolidated lung, then it should be drained. A mild degree of pleural effusion may resolve without drainage after 48–72 hours on the appropriate antibiotic therapy. Tubes are placed in the ventral-most aspect of the chest cavity, at a site deemed appropriate based on ultrasonographic evaluation. This clinician prefers to leave the chest tube indwelling with a one-way Heimlich valve. The size of the tube used should be based on the width of the rib space, character of the fluid, and quantity of fibrin. Based on these criteria, argyle trocars ranging from 20 French to 32 French are most often used. The site is selected and local anesthesia is used to block the skin and cranial aspect of the rib margin prior to placement of the tube.

The tube may then be removed after 48–72 hours if fluid ceases to re-accumulate or stops draining from the tube. Clamping of the tube for 12 hours may be helpful in determining whether fluid production has ceased. The author flushes the indwelling tube every 4–6 hours to minimize obstruction with fibrin.

Pleural lavage with sterile fluids is of benefit if proper egress can be established. It allows for removal of some fibrin and pro-inflammatory cytokines. Horses have an incomplete mediastinum. As such, drainage of one side may allow for drainage of the opposite hemithorax if the mediastinum is not obstructed with fibrin.

Concurrent intravenous fluid may be warranted during drainage if removal of a large quantity of fluid (5–10 L) is anticipated, given that pleural drainage will result in a reduction in central venous pressure, reduce preload, and hence, cardiac output. Nonsteroidal anti-inflammatory therapy is used to decrease inflammation and minimize the effects of endotoxemia. A single dose of corticosteroids is sometimes used to reduce inflammation in the acute stages.

**Bronchial Lavage**

This procedure is used in some cases to evacuate the affected small airways of exudate. This is performed under endoscopic guidance. An affected bronchus is identified and 25 mL of 2% lidocaine infused into the airway. The airway is then flushed with saline, and the dislodged exudate aspirated and discarded.

**Thoracoscopy**

Thoracoscopic evaluation of the affected hemithorax allows for more efficient pleural lavage, and targeted fibrin removal and adhesiolysis.

**Thoracotomy and Rib Resection**

This procedure is recommended for chronically affected patients who have a large degree of fibrin or exudate in the affected hemithorax and are still experiencing febrile episodes. It allows for removal of necrotic lung and fibrin from the chest cavity. Prior to surgery it should be determined whether the mediastinal communication is closed. If still incomplete, the procedure may result in severe bilateral pneumothorax.
Complications

The most common complication seen is pleural abscess formation. Laminitis secondary to the severe endotoxemia seen in the more severe cases may also occur. Pneumothorax is most often seen in association with pleuropneumonia, and may be diagnosed via thoracic radiography or ultrasound.

8. Pneumothorax and Hemothorax

Pneumothorax occurs when there is a collection of air within the pleural space. It leads to collapse or retraction of the lung away from the parietal pleura or internal thoracic wall, and is often associated with respiratory distress. Pneumothorax is most often seen secondary to pleuropneumonia; however, may also occur secondary to trauma involving the thoracic cavity or less often as a sequelae of surgery of the upper respiratory tract.

Hemothorax refers to the accumulation of blood within the pleural space, and is most often seen secondary to trauma involving the thoracic cavity. It has also been documented to occur secondary to the intravenous administration of phenylephrine in older horses, although the incidence of this complication is rare.

9. Clinical Examination

Either condition is often associated with tachypnea, dyspnea, tachycardia, and cough. Tachycardia and pale mucous membranes may be particularly associated with hemothorax. Thoracic auscultation may reveal an absence of normal bronchovesicular lung sounds in the affected hemithorax. Subcutaneous emphysema may also be detected in the thoracic wall. For the patient with pneumothorax, the absence of lung sounds will be noted in the mid-to-dorsal aspect of the affected hemithorax whereas an absence of lung sounds in the mid to ventral hemithorax will be seen in the patient with hemothorax.

10. Diagnosis

Either condition should be strongly suspected with a history of thoracic trauma. Pneumothorax should be suspected if there is a history of pleuropneumonia and may be related to the primary disease process or may occur as a complication of an indwelling chest tube. Thoracic ultrasound may be performed in the field to confirm the presence of blood in the thoracic cavity, which will appear as hyperechoic fluid between the visceral and parietal pleural surfaces. If active bleeding is still present, consistent swirling within the fluid may be present. With pneumothorax, thoracic ultrasound may also reveal the lack of contact and movement of the visceral pleural surface against the parietal pleura in the dorsal lung field. Radiographs of the thoracic cavity are indicated to confirm the presence of pneumothorax. If present, retraction of the lung from the diaphragm caudally and vertebral bodies dorsally will be observed.

11. Treatment

Treatment of hemothorax may involve drainage of the fluid from the affected hemithorax to allow for re-expansion of the lungs. However, the decision to drain should be based on the degree of respiratory compromise and quantity of fluid present in the affected hemithorax. Thoracocentesis and drainage should be performed only if active bleeding has ceased. Identifying landmarks for placement of a chest tube are similar to the protocol described in the section on bacterial pleuropneumonia. A whole-blood transfusion may be warranted prior to considering drainage of blood from the affected hemithorax. Indications for a transfusion include a low packed cell volume in the range of 12–15% or lower, with concomitant tachycardia and tachypnea.

Treatment of pneumothorax should be considered once confirmed with the use of both ultrasonography and radiography. Any open penetrating wound that may be contributing should be immediately packed and an airtight pressure bandage applied. Thoracocentesis with aspiration of the free air can then be performed to re-establish negative pressure within the pleural space. A teat cannula or thoracostomy tube may be used to insert into either one of the intercostal spaces of the twelfth to fifteenth ribs. The air may then be slowly removed with use of a 60-cc syringe or a suction device. The tube may be left indwelling with a one-way Heimlich valve if continued escape of air into the pleural space is anticipated.

Pneumothorax associated with pleuropneumonia warrants a poor prognosis. Pneumothorax associated thoracic trauma or upper airway surgery carries a more favorable prognosis.

12. Rib Fractures in Foals

Rib fractures occur with relative frequency in newborn foals. Incidence rates range from 20–65% based on retrospective and prospective studies. A higher incidence rate in fillies has been reported, and the ribs of the left hemithorax seem to be most susceptible to trauma. An increased incidence in foals born to primiparous mares has not been observed contrary to popular belief. In most instances, the rib fractures are of little clinical significance; however, depending upon their location and degree and manner of displacement they have the ability to inflict severe damage to organs within the thoracic cavity with sometimes fatal consequences. Hemothorax, pneumothorax, diaphragmatic rupture, hemoabdomen, cardiac puncture, and sudden death may occur as a sequelae.

13. Clinical Examination

Clinical examination of any neonate should involve particular attention to the thoracic cavity. It should begin with assessment of the foal’s respiratory pattern. Tachypnea and nostril flare with short shallow breaths may suggest the presence of
thoracic trauma and rib fractures. The pain involved may also prohibit the foal from ambulating willingly as well as lying down in a normal manner. Observation for any abnormal swellings of the thoracic cavity or ventral edema under the mediastinal region may also be suggestive of thoracic trauma. The foal’s rib cage should be palpated with the foal standing for assessment of symmetry. Displaced rib fractures may elicit a palpable click during the respiratory cycle. The rib cage should also be examined with the foal in dorsal recumbency with its forelimbs extended to assess for any visible depressions in the thoracic wall.6

Thoracic auscultation may reveal harsh lung sounds if there is a significant component of pulmonary contusions and thus pleural roughening. A click emanating from a fracture site may also be auscultated during the respiratory cycle. Diminished or absent bronchovesicular lung sounds may suggest the presence of either hemothorax or pneumothorax.

14. Diagnosis
If abnormalities on the clinical examination are suggestive of the presence of rib fractures, further diagnostic investigation is warranted to determine whether interventional therapy or triage to a tertiary care facility is warranted. Normal thoracic symmetry does not exclude the possibility of the patient having a rib fracture.6 Historically, radiographs of the thoracic cavity have been used to detect rib fractures, although the sensitivity of this modality is considered poor based on the location of most fractures at the costochondral junction. Overlying lung pathology or abdominal viscera may prohibit adequate visualization of fractures at this location. Use of ultrasonography has been shown to be four times as sensitive as radiography in detection of rib fractures in equine neonates.6 Ultrasonography also allows for the detection of soft tissue abnormalities of the thoracic wall such as hematomas. Fractures and their degrees of displacement can be documented.6

Ultrasonography may be performed with a 7.5–10-MHz linear probe. With the foal in lateral recumbency and the upper limb extended, the ribs are ultrasonicated from the costovertebral junction to the costochondral junction in both the transverse and longitudinal views. Ribs two through seven are the most likely to sustain trauma during parturition. Fractures associated with ribs three through six in the left hemithorax carry a greater risk of trauma to the thoracic organs due to their proximity to the heart.7 The normal rib margin should appear as a hyperechoic line that should be contiguous with the more hypoechoic costal cartilage. Any break in the contour of the rib margin or displacement between the rib margin and costal cartilage is suggestive of a rib fracture (Fig. 5). At the same time the lungs should be ultrasonicated to ascertain whether the lung has sustained any contusions or for the presence of hemothorax or pneumothorax. Evaluation of the thoracic cavity should ideally be performed with the patient standing to maximize the ability to detect these abnormalities.

15. Treatment
Most rib fractures do not pose a clinical problem for the patient. Fractures located in the cranial and ventral half of the thorax, especially those of the left side associated with ribs three through six often require surgical intervention due to their proximity to the heart. Complete fractures of two or more ribs with axial deviation of either fracture fragment should also be considered for surgical correction, especially if located over the heart.

If either hemothorax or pneumothorax are detected, then further intervention is certainly warranted. One should anticipate that if a hemothorax is corrected via thoracocentesis and drainage that a pneumothorax may follow as the lung re-expands and comes in contact with the displaced rib fragment. Thus, surgical correction of the rib fracture should be performed simultaneously to prevent secondary complications. In one report the fourth and fifth ribs were the most frequently surgically reduced pair.7 Many methods of repair have been documented, including the use of reconstruction plates, cerclage wires, nylon cable ties, and nylon strand suture.7,8,9

16. Acute Respiratory Distress Syndrome in Foals
Acute respiratory distress syndrome (ARDS) is a life-threatening condition characterized by widespread inflammation of the lungs. Risk factors for development include primary lung injury such as pneumonia or aspiration, or nonpulmonary conditions such as severe sepsis.10 A few reports have documented this condition in foals, with their ages ranging from 1 to 12 months of age.11,12 An acute onset, the presence of pulmonary infiltrates in both lungs, a ratio of PaO2 (partial pressure of arterial
less than or equal to 200 mm Hg characterize the acute lung injury, which is defined by a ratio of PaO2 to FiO2 of less than or equal to 300 mm Hg.10

17. Clinical Examination
Fever, tachypnea, and tachycardia are common clinical findings. Lung auscultation may reveal reduced bronchovesicular lung sounds with the presence of diffuse adventitious lung sounds.

18. Diagnosis
A history of acute onset of respiratory distress, moderate leukocytosis and neutrophilia, hyperfibrinogenemia, and an elevated SAA are all supportive of the condition. Hypoxemia and the presence of diffuse interstitial or bronchointerstitial radiographic pattern along with pulmonary infiltrates are confirmatory characteristics of the condition. Despite the visible severity of respiratory embarrassment, thoracic ultrasound typically reveals the presence of only mild comet tail artifacts emanating from the pleural surface of either lung. Transtracheal wash may yield growth of a variety of different types of bacteria. A viral component has not consistently been identified in association with the condition.

19. Treatment
Treatment involves intranasal oxygen therapy. A second nasal cannula may be warranted if initial therapy fails to improve the PaO2.11 Due to the variety of bacteria that may be isolated, broad-spectrum antibiotic therapy is recommended. If *Rhodococcus equi* is suspected as a contributor, antibiotic therapy should be tailored toward treatment of this organism. Inhalational therapy with antibiotics such as ceftriaxone at a dose of 2.2 mg/kg once a day1 may also be considered if the severity foal’s condition allows it to tolerate the mask for nebulization. The effectiveness of this modality to deliver drugs into the compromised alveolar space is questionable. Administration of corticosteroids, although generally considered to be contraindicated for use with respiratory disease with a bacterial component, is with a critical component of treatment of this condition. In one study describing a syndrome resembling ARDS, few foals survived; however, those that did were treated with parenteral corticosteroids in addition to broad-spectrum systemic antimicrobials.12 In a retrospective study looking at the management of ARDS/acute lung injury in 5 foals, there was a 60% survival rate, with 13 of 15 foals having been treated with parenteral corticosteroids in conjunction with antibiotics.11 Of the two foals not treated with corticosteroids, one survived and one was subjected to euthanasia. The use of non-steroidal anti-inflammatory therapy is also indicated to address the widespread inflammation and fevers that these patients are subjected to. The use of bronchodilator therapy in ARDS is controversial. There have been no studies in equines to demonstrate their benefit in the treatment of ARDS. The nebulization route of therapy may be rendered ineffective, given that drugs are unlikely to reach the fluid-filled alveolar space in the consolidated and poorly ventilated lung.10 Although intravenous administration of beta-2 agonists such as albuterol have been demonstrated to reduce airway pressure, resistance, and alveolar fluid in human ARDS patients, their ability to positively affect outcome of these cases has never been demonstrated. In fact, in one study evaluating the outcome of intravenous salbutamol in human patients with ARDS, the mortality rate was higher in the salbutamol group vs the placebo group. The patient’s dependence on the ventilator was also increased in the salbutamol group.10

Prognosis for survival in foals afflicted with ARDS is considered poor; however, treatment with a combination of systemic corticosteroids, broad-spectrum antimicrobials, and inhalational oxygen may positively affect the outcome of these cases.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflict of interest.

References


Emergency Neonatal Triage for Sepsis

Nathan M. Slovis, DVM, DACVIM, CHT

The equine triage and techniques described in this article are intended to be used by the field practitioner. In-depth techniques used at a tertiary referral clinic will not be discussed. Author’s address: Hagyard Equine Medical Institute, 4250 Iron Works Pike, Lexington, KY 40511; e-mail: nslovis@hagyard.com. © 2016 AAEP.

1. Introduction
The transformation from fetus to neonate represents a series of rapid and dramatic physiologic changes during which the placenta is replaced by the lungs as the primary organ of gas exchange. The transition goes smoothly most of the time; however, in human medicine (we do not know in equine medicine), approximately 10% of the time active intervention of a skilled individual or team is necessary to ensure that the newborn receives the appropriate assistance to assume independent existence as quickly as possible.1 Ideally, whenever a foal is delivered appropriate equipment (Table 1) should be close and easily accessible. These supplies should be routinely checked for completeness, good working order, and expiration dates. A delay in effective resuscitation may occur if someone needs to leave the “scene” during the procedure to obtain an essential piece of equipment. The need for full resuscitation, including chest compressions or medical administration or both, is relatively rare, occurring in humans approximately 1–2 per 1000 live births.2 Cardiopulmonary cerebral resuscitation in humans has a success rate between 10 and 15%; in veterinary medicine, the success rate is less than 10%.3–6 Resuscitation is only the beginning. Owners must realize that the initial event causing respiratory or cardiac arrest, as well as hypoxia (reduction of oxygen supply to tissues) that occurs during arrest, can cause more problems for the foal. Thus, referring a resuscitated foal to an intensive care facility for further evaluation is appropriate.

The approach to the management of the sick foal will vary depending on the size of the breeding establishment involved, the economic value of the foal, and environmental, geographic, and seasonal factors. All of these factors should be taken into account when advising each owner of the best intervention to help mitigate any potential issues. The use of “risk categories” for foals is very helpful for veterinarians in determining the stage and speed of intervention. The use of examination forms and foaling charts can be useful as they may guide future decision making and also be useful if the animal is later assessed by another practitioner.

2. Risk Categories
I. Low Risk
A. No maternal, neonatal, or environmental risk factors have been identified (see Risk Factors section)
B. Gestation was of normal duration
   i. Pony breeds, 320–345 days
Thoroughbred, 320–360 days
Donkeys, 360–380 days

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C. Normal parturition; stage 2 labor lasted \( \frac{20}{H11349} \) minutes and no significant manipulation of the foal was required for delivery

D. Normal postpartum events

i. Foal stood within 2 h of delivery

ii. Foal nursed within 3 h of delivery

E. Placenta is visually normal and \( \leq 10–12\% \) of weight of foal.

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**Table 1. Recommended Emergency Supplies for Resuscitation Kit**

<table>
<thead>
<tr>
<th>Supplies</th>
<th>Description</th>
<th>Dose/Route</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full oxygen tank (optional)</td>
<td>Hydroxyethyl starch volume expander</td>
<td>.01 to .02 mg/kg IV (50kg Foal: 0.5 to 1 ml IV at 3 min increments until return of circulation)</td>
</tr>
<tr>
<td>Ambu resuscitator with 3 ft</td>
<td>Hypertonic saline</td>
<td>Have three 1 cc syringes drawn up</td>
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<tr>
<td>corrugated tubing tail piece</td>
<td>Isotonic polyionic fluids (Lactated Ringer's Solution, etc.)</td>
<td>Have two 1 cc syringes drawn up</td>
</tr>
<tr>
<td>Endotracheal tubes (7, 8 and 9 mm for foals)</td>
<td>Fluids</td>
<td>Have two 1 cc syringes drawn up</td>
</tr>
<tr>
<td>Fluids</td>
<td>50% Dextrose</td>
<td>0.022 mg/kg IV (50 kg foal: 0.5 cc IV)</td>
</tr>
<tr>
<td>Fluid administration sets (include a pressure bag for rapid administration of fluids)</td>
<td>50% Magnesium Sulfate</td>
<td>Have two 1 cc syringes drawn up</td>
</tr>
<tr>
<td>Fluid additives</td>
<td>Tubing</td>
<td>0.75 mg/kg IV</td>
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<tr>
<td>Oxygen supplies</td>
<td>Nasal cannula</td>
<td>Have bottle available</td>
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<tr>
<td></td>
<td>Humidifier and connectors</td>
<td>Give 0.5 to 1.5 cc IV per 100 pounds</td>
</tr>
<tr>
<td>Intravenous catheters</td>
<td>Xylazine</td>
<td>Have two 4 mg bottle available</td>
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<tr>
<td>Feeding tubes, 24 Fr, 60 in long</td>
<td>Detomidine</td>
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<tr>
<td>(Harris Flush Tube or Stallion Urinary Catheter)</td>
<td>Romifidine</td>
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<tr>
<td>Sedatives for the mare</td>
<td>Epinephrine 1mg/ml</td>
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<tr>
<td></td>
<td>Doxapram 20 mg/ml (respiratory stimulant)</td>
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<tr>
<td></td>
<td>Glycopyrrolate 0.2 mg/ml (anticholinergic agent used to treat bradyarrhythmias)</td>
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<tr>
<td></td>
<td>Yohimbine (alpha 2 adrenergic antagonist - used for dystocias or C-Sections in which the mare is heavily sedated with an alpha2 adrenergic agonist)</td>
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<tr>
<td></td>
<td>Naloxone (narcotic antagonist - used in C-Section foals to help reduce the endogenous opioids that cause mental depression)</td>
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<tr>
<td></td>
<td>Methylprednisolone sodium succinate</td>
<td>2 mg/kg IV</td>
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<tr>
<td></td>
<td>Lidocaine 2% (for ventricular tachycardia)</td>
<td>Have two 500 mg preservative-free bottles available</td>
</tr>
<tr>
<td></td>
<td>Furosemide (diuretic - use for pulmonary edema)</td>
<td>1 mg/kg IV</td>
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<tr>
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<td>Naloxone (narcotic antagonist - used in C-Section foals to help reduce the endogenous opioids that cause mental depression)</td>
<td>1 mg/kg IV</td>
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<td>Methylyprednisolone sodium succinate</td>
<td>Have bottle available</td>
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<tr>
<td></td>
<td>Epinephrine 1mg/ml</td>
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<tr>
<td></td>
<td>Doxapram 20 mg/ml (respiratory stimulant)</td>
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<td></td>
<td>Epinephrine 1mg/ml</td>
<td></td>
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<td></td>
<td>Doxapram 20 mg/ml (respiratory stimulant)</td>
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<td>Methylprednisolone sodium succinate</td>
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<tr>
<td></td>
<td>Lidocaine 2% (for ventricular tachycardia)</td>
<td>Have two 500 mg preservative-free bottles available</td>
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</tbody>
</table>

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ii. Thoroughbred, 320–360 days

iii. Donkeys, 360–380 days

C. Normal parturition; stage 2 labor lasted \( \leq 20 \) minutes and no significant manipulation of the foal was required for delivery

D. Normal postpartum events

i. Foal stood within 2 h of delivery

ii. Foal nursed within 3 h of delivery

E. Placenta is visually normal and \( \leq 10–12\% \) of weight of foal.
Low-risk foals should receive a thorough clinical examination and determination of serum IgG status between 12 and 24 hours of age. Any abnormalities found during the examination should guide the selection for further diagnostics.

II. Moderate- and High-Risk Foals

Moderate-risk foals have been described as foals that have only one risk factor of maternal, environmental, or foal origin. These foals, if not treated correctly, can quickly become high-risk foals, so low- and high-risk foals should initially be approached in the same manner. High-risk foals are those that have more than one risk factor.

Many of the risk factors involved (maternal illness or concurrent infectious disease on the premises) are identified before delivery and allow for anticipation of problems and warrant early intervention. In addition to the clinical examination outlined below that will take place at an earlier stage following birth, additional measures should be taken:

A. Frequent monitoring of the foal for signs of deterioration or absence of normal developmental steps (e.g. failure to nurse, urinate, etc.)
B. Serum chemistry with electrolyte evaluation
C. Serial monitoring of complete blood count (CBC)
D. Serum IgG levels, IgG may be rapidly consumed in these foals and repeat analysis is advisable
E. Frequent monitoring of body weight (BW). Foals should gain on average of 2 pounds daily.
F. Determine whether chemoprophylaxis is warranted
   i. Low white blood cell (WBC) count
   ii. Placental pathology
   iii. Mare with significant risk factors
   iv. Foal with failure of passive transfer

Maternal Risk Factors
1. Dystocia
2. Caesarian section
3. Partial or complete premature placental separation
4. Medically induced labor
5. Parturition prior to 320 days’ gestation
6. Placentitis
7. Concurrent illness or fever
8. Recent medical or surgical event
9. Recent transport stress
10. Twin pregnancy
11. Vaginal discharge
12. Chronic lameness or incoordination
13. Premature lactation
14. Agalactia
15. Prolonged gestation with oversized foal (uncommon)
16. Pelvic abnormalities

<table>
<thead>
<tr>
<th>Table 2. Complete Blood Count in Foals &lt;24 Hours of Age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age &lt;24 h.</td>
</tr>
<tr>
<td>WBC, k/UL</td>
</tr>
<tr>
<td>RBC, m/UL</td>
</tr>
<tr>
<td>HGB, g/dL</td>
</tr>
<tr>
<td>HCT, %</td>
</tr>
<tr>
<td>PLT, K/µL</td>
</tr>
<tr>
<td>MCV, fl</td>
</tr>
<tr>
<td>MCH, pg</td>
</tr>
<tr>
<td>MCHC, g/dL</td>
</tr>
<tr>
<td>NEUT, %</td>
</tr>
<tr>
<td>LYMPH, %</td>
</tr>
<tr>
<td>MONO, %</td>
</tr>
<tr>
<td>EOS, %</td>
</tr>
<tr>
<td>BASO, %</td>
</tr>
<tr>
<td>NEUT No., K/µL</td>
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</tr>
<tr>
<td>EOS No., K/µL</td>
</tr>
<tr>
<td>BASO No., K/µL</td>
</tr>
</tbody>
</table>

Source: 283 normal Thoroughbred foals within 24 hours of birth: Hagyard Equine Medical Institute.

17. Drug related; sedatives, beta-2 agonists, nonsteroidal anti-inflammatories
18. Previous history of dystocia, delivery of septic foal, or neonatal isoerythrolysis foal

Neonatal Risk Factors
1. Twins
2. Premature/dysmature
3. Death of the dam
4. Meconium staining
5. Foals that do not stand and nurse by 3 h of age
6. Failure of passive transfer

Environmental Risk Factors
1. Foaling in contaminated area
2. Foaling in cold or wet conditions
3. Infectious disease on the premises
4. Disrupted foaling

3. Hematology and Serum Biochemistry

Knowing normal values for the neonate is important when assessing the foal’s blood values. Most commercial laboratories will have the normal ranges for adult animals and therefore the practitioner must know what is normal for a foal so that proper interpretation can be achieved (Tables 1, 2, and 3).

Alterations in the Total WBC Count Values

Leukocytosis can be characteristic for a newborn foal that had an infection in utero and is rarely associated with physiologic causes (stress, excitation, and exercise). Leukopenia is considered by the author to be always pathologic. In summary, foals with a WBC count of greater than 15,000 or less than 5000 and an absolute neutrophil count less...
than 1000 cells/μL with one or more factors should be candidates for antimicrobial therapy.

Serum Amyloid A could also be performed as an acute marker for inflammation on high-risk foals and to the authors experience anything greater than 100 μg would be a risk factor for a foal to develop clinical disease.

Serum creatinine is usually an unreliable marker for renal disease because the placenta is primarily responsible for elimination of waste from the fetus. Therefore, an increase in creatinine is usually a reflection of placental dysfunction and not indicative of renal dysfunction. However, if levels continue to increase or do not decrease in 2–3 days’ time, then renal insufficiency may be the cause.7

Creatinine kinase is monitored routinely in our clinic’s blood work because subtle increases can be a marker for perinatal asphyxia. This elevation could be the result of tissue hypoxia that occurred during the foaling process or placental insufficiencies and could be elevated due to trauma of birth origin or prolonged recumbency.

Alkaline phosphatase (ALP) isoenzymes are found in every tissue with high activities in the liver, bone, intestine, kidney, and placenta. Neonates can be expected to have values of 100× that of adults for the first 10 days of life, especially after the ingestion of colostrum.

γ-Glutamyltransferase (GGT) activity in foals can be noted to be significantly increased over that in the adult horse for the first month of life. GGT activities in the foal are not the result of colostrum absorption but primarily due to endogenous sources. The ratio of hepatic weight to total BW is greatest in foals and decreases with age. This relative disparity in hepatic mass may account for some or all of the increases in GGT values in foals. Human fetal hepatic tissue is reported to have specific activities of GGT 10× higher than those in adults.8

Sorbitol dehydrogenase (SDH) should be in the foal reference range like that of an adult, but with tissue hypoxia, sorbitol dehydrogenase can be elevated and is used by the author as a marker to determine the risk of perinatal asphyxia syndrome.

4. **Neonatal Sepsis (Systemic Inflammatory Response Syndrome, Multiple Organ Dysfunction Syndrome [MODS])**

Sepsis, despite the advancement of equine neonatal care, is still implicated as the major cause of morbidity and death (up to 50%) in equine neonates.9–10 Sepsis refers to the development of a systemic inflammatory response syndrome to a confirmed infectious process. Clinical signs of neonatal sepsis are nonspecific and cannot be used to predict which bacterial isolate is the causative organism. Diagnosis of sepsis remains somewhat illusive in neonates. Blood cultures for pathogens continue to be the gold standard for diagnosis; however, clinical signs consistent with sepsis in the face of negative cultures can be frequent and is referred to as “clinical sepsis.” This clinical sepsis may reflect a suppression of growth from maternal antibiotic administration or noninfectious triggering of the innate immune system known in humans as the “inflammatory baby.” This systemic inflammatory response results from the dysregulation of systemic host response to cascading inflammatory and anti-inflammatory mediators induced by infecting organisms.2

### Table 3. Serum Biochemistry Normal Reference Range in Foals Up to 4 Days of Age

<table>
<thead>
<tr>
<th>Foals up to 4 Days of Age, Mean</th>
<th>1 SD</th>
<th>CV</th>
<th>Foals to 4 Days Old, Normal Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sodium</td>
<td>137.75</td>
<td>3.338</td>
<td>2.423</td>
</tr>
<tr>
<td>Potassium</td>
<td>3.867</td>
<td>0.404</td>
<td>10.45</td>
</tr>
<tr>
<td>Chloride</td>
<td>99</td>
<td>4.28</td>
<td>4.323</td>
</tr>
<tr>
<td>CO₂</td>
<td>30.15</td>
<td>3.76</td>
<td>12.47</td>
</tr>
<tr>
<td>Glucose</td>
<td>141.45</td>
<td>17.796</td>
<td>12.58</td>
</tr>
<tr>
<td>BUN</td>
<td>18.8</td>
<td>3.82</td>
<td>20.32</td>
</tr>
<tr>
<td>Creatinine</td>
<td>2.01</td>
<td>0.579</td>
<td>28.81</td>
</tr>
<tr>
<td>Calcium</td>
<td>11.505</td>
<td>0.472</td>
<td>4.103</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>5.4</td>
<td>0.434</td>
<td>8.037</td>
</tr>
<tr>
<td>Total protein</td>
<td>5.235</td>
<td>0.597</td>
<td>11.4</td>
</tr>
<tr>
<td>Albumin</td>
<td>2.925</td>
<td>0.192</td>
<td>6.564</td>
</tr>
<tr>
<td>Alkaline phosphatase</td>
<td>2041.6</td>
<td>448.765</td>
<td>21.98</td>
</tr>
<tr>
<td>Gamma glutamyl transferase</td>
<td>32</td>
<td>9.504</td>
<td>29.7</td>
</tr>
<tr>
<td>AST</td>
<td>134.842</td>
<td>50.115</td>
<td>37.17</td>
</tr>
<tr>
<td>LDH</td>
<td>578.053</td>
<td>128.377</td>
<td>22.21</td>
</tr>
<tr>
<td>CK</td>
<td>630.331</td>
<td>424.489</td>
<td>67.34</td>
</tr>
<tr>
<td>Total bilirubin</td>
<td>3.35</td>
<td>0.728</td>
<td>21.73</td>
</tr>
<tr>
<td>Total No. samples</td>
<td>20</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: Hagyard Equine Medical Institute, Clinical Laboratory. Performed on 20 healthy Thoroughbred foals ≤ 4 days of age.

BUN = blood urea nitrogen; AST = aspartate transaminase; LDH = lactate dehydrogenase; CK = creatine kinase.
plexfity of the responses in the pathway of systemic inflammatory response syndrome. As of now, managing sepsis in the neonatal foal will remain grounded on the same cornerstones that were established more than two decades ago: infection control (antimicrobials, plasma, drainage), hemodynamic supportive therapies (crystalloid fluids, colloids, plasma, vasopressors), respiratory support (nasal oxygen, ventilation), and nutritional support.10

5. Treatment

Infection Control

Antimicrobials are aimed at broad-spectrum coverage of the most likely organisms. As equine ambulatory practitioners tend to examine the patient before referral to the hospital, they can implement antimicrobial treatment before referral to the hospital. If the referral hospital is just minutes away, then blood cultures should ideally be obtained before the start of antimicrobial treatment. However, if the trip is longer than 45 minutes, then it is strongly recommended that antimicrobial therapy be initiated at the farm. Once organisms are identified, specific therapy is initiated. Antimicrobials commonly used at the author's referral practice include (remember that therapeutic drug monitoring is recommended for aminoglycosides):

- Amikacin, 20–25 mg/kg IV or IM q 24 h
- Ampicillin, 20 mg/kg IV q 6–8 h
- Cefotaxime, 40 mg/kg IV q 6 h
- Ceftazidime 40–50 mg/kg IV q 6–8 h
- Ceftiofur, 5–10 mg/kg IV, IM or SQ q 6–12 h
- Gentamicin, 8–15 mg/kg IV q 24 h
- Metronidazole, 10 mg/kg PO or per rectum q 12 h
- Potassium penicillin, 22,000 IU/kg IV q 6 h

Hemodynamic Support

Fluid therapy is a universal therapeutic modality used in critical-care patients. It is considered the second most important component in equine neonatal sepsis. Hypovolemia, which can occur in cases of severe sepsis, septic shock, high-volume diarrhea, or acute hemorrhage, demands immediate intervention. A balanced isotonic fluid is an appropriate fluid for resuscitation. Some studies have recently noted that excessive chloride concentration of the fluid may have negative effects on renal function. Therefore, avoid isotonic saline and use fluids with lower chloride levels such as Normasol R® or Plasmalyte A® for resuscitative fluids. The author tends to deliver a fluid bolus of 20 mL/kg delivered (without additives) over 5–20 minutes with a reevaluation of perfusion after the bolus. This re-evaluation includes perfusion parameters such as pulse quality, extremity temperatures, return of borborygmi, improving lactate parameters, urine production, improved mental status, and improved blood pressure status. Always assess the glucose levels of the patient, because septic patients are often hypoglycemic, which necessitates the use of glucose in the fluids (if you are bolusing the fluids, then the addition of 25 cc of 50% dextrose may be appropriate to raise the glucose levels out of the critical range). Repeated fluid boluses are not uncommon when treating septic shock with most neonates receiving between 20 and 40 mL/kg bolus. If signs of hypoperfusion are still present after giving 60 mL/kg boluses, then vasopressor therapy should be initiated.11 The use of synthetic colloids is controversial for septic shock. One study using antiendotoxin plasma on survival in septic and critically ill foals documented a higher survival rate to discharge with use of antiendotoxic plasma compared with foals receiving another plasma type.12 The author, after fluid resuscitation in the septic foal, will also use antiendotoxin plasma at a dose of 20 mL/kg with 2000 IU/L of heparin added before administration. Once perfusion parameters have been normalized, then a transition to maintenance fluids can be implemented. It is very important to prevent overloading the neonate with sodium because of their natural sodium-conserving physiology. Remember that milk is a low in sodium and considered a high-potassium source for the foal; therefore, we want to administer fluids that are physiologically equivalent to our patient needs. Examples of maintenance fluids in foals include Plasmalyte 56, Normosol M, 0.45% saline and 0.45% saline and 2.5% Dextrose. All of these fluids have 40 meq/L of Na and Cl. The author tends to give his neonates a maintenance rate of 3–4 mL/kg/h (which comes out to be roughly 1 L of crystalloids q 6 h for a 60-kg foal).
A. Example: 50-kg Foal × 0.07% BW = 3.5 L of milk or replacer per day. 3500 mL/12 = roughly 300 mL every 2 h via the nasogastric tube. If foal tolerates this well then increase by 1–2% BW every 12–24 h

Some of these foals could have some lactase deficiency and may require the need for lactase supplementation while the gastrointestinal tract heals.

II. 1500–3000 IU Lactased orally every 4 h
Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnotes


*Hospira Inc, Lake Forest IL 60045.*

*Abbott Laboritories, North Chicago IL 60064.*

*EquiPlas Plus, Plasvacc USA Inc., Templeton, CA 93465.*

*Lactaid Original.*
Giving the Broken Horse a Break: Some Practical Practices in Orthopedic First Aid

Dean W. Richardson, DVM, DACVS

Author’s address: University of Pennsylvania, School of Veterinary Medicine, Department of Clinical Studies, 382 West Street Road, New Bolton Center, Kennett Square, PA 19348; e-mail: dwr@vet.upenn.edu. © 2016 AAEP.

1. Introduction

Genuine emergencies are genuinely stressful! No one can argue that point but clients rely on their veterinarian not only to deal with the situation but also to help them make the best decision. With proper sedation and simple emergency bandaging, a large proportion of “catastrophes” can be humanely managed until a thoughtful decision has been made.

Recommendations for the selection and application of splints have been published. An excellent online graphical reference can be found at the following link: https://www.acvs.org/sites/default/files/files/EQ_Frac_SplintingChart.pdf. A more text-based online resource can be found at http://www.merckveterinarymanual.com/mvm/emergency_medicine_and_critical_care/equine_emergency_medicine/equine_trauma_and_first_aid.html.

Perhaps the most critical determinant of the outcome for a horse with an extremely unstable injury of the distal limb (radius/tibia down to the hoof) is whether or not the skin remains intact and how much soft tissue and further bone injury occurs prior to surgical treatment. Proper splinting during transportation may well be a life-saving procedure. Having some appropriate materials immediately available can make all the difference. The most versatile and inexpensive material remains thick-walled PVC pipe (~6-in diameter) cut into staves of appropriate curvature and length. The PVC can be readily cut to length with just about any type of saw in a field situation. It is strong, light and the curvature of variously cut 6-inch pipe staves will generally fit a reasonably padded bandage. Other materials (electrical conduit, rebar, strong-enough/light-enough wood, thermoplastics, molded fiberglass cast tape) can be used but for ease of use and price, the simple PVC staves are the most practical and versatile.

2. Errors in Fracture Assessment

The biggest mistake that can be made by an attending veterinarian is acting without appropriate knowledge. A rush to euthanasia is certainly indicated in terribly catastrophic injuries but euthanasia is exceptionally difficult to reverse so it should not be done immediately if you are even slightly uncertain about the “fixable” nature of the injury. The reality is that many severe lacerations and orthopedic injuries seem to be far worse than they are. In today’s information-rich world, it is both possible and undesirable to have an owner find out after a horse has been euthanized that there have been other horses with the same injury successfully treated.
treated. Be wary of offering a prognosis unless you really do know a lot about that specific injury. Have a good relationship (more importantly, their cell phone number) with an expert (or experts) whom you trust to provide an accurate second opinion.

It is impossible to offer strict “rules” on whether or not an individual horse with a given fracture has a chance to be successfully treated. (It is a reliable rule that euthanized horses never heal.) Some generalizations about fracture “treatability” are possible, however.

1. A skin wound over a fracture is not a death sentence. Contamination of a fracture is a tremendously important consideration but simple observation of a wound is not evidence that the prognosis is hopeless. The most obvious examples are ulnar fractures secondary to kicks. The laceration is often proximal and superficial to the fracture and rarely results in unmanageable infection.

2. Any nondisplaced fracture of any bone has a chance to heal. There is no reason you must summarily euthanize a horse with a fissure fracture, even if it is non-weightbearing. Not every horse with a non-weight-bearing lameness will develop support limb laminitis.

3. Simple fractures are nearly always more manageable than comminuted fractures but location is everything. Comminuted fractures of the phalanges are often salvaged, some even to useful activity, but the more proximal the fracture is on the limb, the more improbable it is that it can be saved with surgical treatment. In contrast, comminuted humeral fractures have been successfully managed with nothing more than stall rest. More hospitals today have options for long-term sling management, which should allow for more horses to survive.

4. Articular fractures are always more serious if athletic soundness is demanded as an outcome. Articular fractures are not necessarily worse if the involved joint can be fused as part of the fracture repair. This definitely includes the carpus, fetlock, and interphalangeal joints.

5. Fractures with major vascular compromise, i.e., true loss of blood supply, are nearly always fatal but a dramatic quantity of visible blood does not equate to loss of vascularity. Fracture severity does not typically correlate with hemorrhage.

3. Errors in Wound Management
Wound management is usually very difficult in a seriously injured horse. If you have a truly severe fracture that will require emergency surgery it will be nearly impossible to do a meaningful debridement. Valuable time and resources will be spent attempting a procedure that will need to be repeated. It is probably wiser in such instances to wrap the site up in an antiseptic soaked gauze and ship to a referral facility as quickly as possible. Broad spectrum antimicrobials should be administered intravenously if a wound is evident in a horse with a suspected fracture.

4. Errors With Splinted Coaptation
The most common errors with a splinted bandage are listed below:

Applying Too Much Bandage Material
An excessively heavy splint (e.g., a 2x4) will often make the limb more cumbersome and possibly serve to worsen the situation. Do your best to get appropriate material. Excess bandage material adds weight to the limb and makes it more awkward for the horse to move. Use just enough padding to allow a tightly wrapped bandage not to act as a tourniquet. The outdated concept that a Robert Jones Bandage needs to be 3–5 times the diameter of the limb is not sound, especially when splints are used. The mechanical value of a splint is diminished the farther it is placed away from the limb. If you use splints, make the bandage light enough to get the splints closer to the skin, but thick enough to prevent trauma from the splint to the skin/soft tissues. Interestingly, there is a recent publication using a bandaging model that supports the mechanical concept that the splint should be close to the skin surface.

Using Elastic Tape
Using elastic tape for attaching a splint will nearly always result in the splint shifting/slipping. Both elastic adhesive (e.g. Elastikon) or self adhesive (Velcro), bandage material are good for incorporating into the bandage itself, but splints should be securely attached with non-elastic material such as duct tape or packing tape. If multiple staves are placed around the limb, metal hose clamps also can assist to help compress the splints against the padded bandage and hold them in alignment.

Incorrect Length of a Splint
Use of a splint that is too short or too long may lead to more harm than good. A good principle is to stabilize the joint above and the joint below the injury. The most common error for cannon bone, carpal, tarsal, radial, and tibial fractures is not to have the splint reach the ground. If the splint does not reach the ground, motion and gravity will tend to shift it down.

Incorrect Placement of Splint(s)
Splinting the incorrect side of the lower limb can be avoided if you remember to apply at least one of your splints to the convex or “open” side of the injury, i.e.,
if the horse’s fetlock is deviated laterally (valgus), place at least one splint on the medial side and incorporate the foot. For severe carpal/tarsal, radial and tibial fractures always have the splint in contact with the shoulder/pelvis.

In severe lower limb injuries (e.g., traumatic disruptions of the suspensory apparatus, comminuted phalangeal fractures), the splint can be used to hold the bones “stacked” vertically as well as possible. A Kimzey Lifesaver splint is easiest if you have it but a simple dorsal PVC splint over a light bandage with the heel taped up to it will work well. Pulling/holding the heel up with the metacarpus and phalanges aligned simulates the position of the Kimzey and is quick and practical.

Another major error to avoid is failure to splint the carpus of a horse with a fractured ulna. Splinting for radial and tibial fractures will afford modest stability and only slightly relieve anxiety but a horse with a properly splinted ulnar fracture will immediately relax and be able to maneuver itself with some confidence.

5. Errors in Transportation

The most common error when shipping an injured horse is to give the horse “as much room as possible” in the trailer/van. Ensuring the horse is shipped in a confined area/stallas possible will allow the horse to protect its injured limb optimally if it can lean its body/shoulder/pelvis against firm support.

The other major shipping error is often made with foal fractures. Foals fatigue quickly when they are stressed and balancing on three limbs. Placement of an intravenous catheter prior to transport may facilitate administration of sedatives/tranquilizers during transport to keep the foal quiet and/or recumbent. Take the time to get the foal in recumbent position on the trailer and, if at all possible, keep an attendant with the foal to maintain it in recumbency during shipping. This is especially important in more proximal fractures that are difficult to stabilize with a splinted bandage, e.g. radius and tibia. Protect the eyes of any recumbent foal/horse during transport.

If possible, ship the horse with the injured limb closest to the rear of the trailer/van. Smooth acceleration (loading the south end of a horse headed north) is easy. Smooth braking is not always possible.

Summary

Most mistakes concerning emergency management of orthopedic injuries are made because decisions and actions are made too quickly. The clinician is always in a high stress situation where the owner is expecting rapid action. The problem is that rapid actions are not always the best action. The clinician should always attempt to quickly stabilize and comfort the patient (and owner) but make no “final” decision, i.e., euthanasia, until options for treatment are at least considered and discussed. It may give some immediate solace to an owner to hear that “nothing can be done for your horse” but today’s world is such that many owners will later discover information that may make them question that decision. It is fair to say that we, as veterinarians, have led to the continued public perception that any seriously injured horse “needs” to be euthanized. Education of the public should eventually result in the understanding that practical considerations ($$$) are the foremost reason to euthanize horses. It is absolutely true that some injuries are so painful and debilitating that our current techniques cannot manage them successfully but we need to have decision making evolve alongside improving techniques.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

How to Improve Your Equine Dentistry Practice by Better Understanding Oral Anatomy

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1. Introduction

Understanding the structure and function of the equine mouth assists veterinarians in recognizing pathology and formulating dental treatment plans. Equine teeth are hypsodont in nature so they are constantly changing through continued eruption and response to wear or trauma. A thorough knowledge of tooth development and wear enables clinicians to optimize oral cavity function in individual horses and avoid causing iatrogenic damage to the teeth and associated structures. One must realize that there is no “ideal” equine mouth and the primary goals of equine dentistry are to minimize pain and maintain function, not to try to shape the teeth to some pre-defined paradigm.

The equine mouth is uniquely adapted for acquisition and initial processing of nutrients to fuel the body. The teeth, gingiva, tongue, palate, and cheeks all play a role in the process of mastication and transport of a food bolus to the pharynx. Although we often think of the oral cavity as having a large empty space similar to a cave, the tongue fills most of the oral cavity between the dental arcades. The cheeks maintain contact with the lateral aspects of the teeth. Because of the proximity of the soft tissues to the teeth, sharp edges on the teeth can cause trauma to the adjacent soft tissues. It is important to understand how the components of the oral cavity function together.

This discussion of oral anatomy begins with the structural anatomy of the equine tooth, reducing it to its component parts, their formation, and relationship to each other. Then, the architecture and function of supporting structures of the tooth are considered. Finally, we examine the spatial arrangement of teeth and their supporting structures within the head to understand their functional interactions. Recently, several authors have written excellent reviews of pertinent equine dental anatomy.1,2 The overall objective of this paper is to review the oral anatomy and physiology of the horse to provide information veterinarians in general practice can use to administer better dental care.

Primary Objectives

- Understand the structure of the dental pulp system, how the hard dental tissues form around it, and why this is important during odontoplasty (floating) procedures.
- Understand how the timing and order of teeth eruption is important and how it can be related to pathologic processes.
- Understand the three-dimensional arrangement of the teeth in relation to the temporo-
mandibular joint and how this is used clinically in the maintenance of function.

- Understand how the hypsodont nature of equine teeth is related to wear and continued eruption of the cheek teeth and incisors.
- Understand the basic defense and repair mechanisms of the teeth and their supporting structures to be able to use this information to develop and implement nonharmful treatment protocols.

2. Definitions

Before the anatomy of the oral cavity is examined in detail, some basic dental terms should be defined:

Apical: A term used to denote a direction toward the root tip.
Occlusal: The table or grinding surface of the tooth.
Coronal: Direction toward the crown.
Proximal (interproximal): Surfaces facing toward adjoining teeth within the same jaw quadrant or dental arch.
Mesial*: The proximal surface facing toward the median line.
Distal*: The proximal surface facing away from the median line of the face.
Vestibular: The preferred term for the surface of the tooth facing the vestibule or lips; buccal and labial are acceptable alternatives.
Lingual: The surface of a mandibular or maxillary tooth facing the tongue (the term “palatal” is often used to refer to the same surface of maxillary cheek teeth).
Anisognathous: The condition of having unequal jaw widths in which the mandibular molar occlusal zone is narrower than the maxillary counterpart

Modified Triadan system: The preferred composite numbering system for the teeth of a horse in which the four dental arcades are numbered 100 (upper right), 200 (upper left), 300 (lower left) and 400 (lower right) and the teeth are numbered from 1 to 11 starting with the central incisor and proceeding to the 3rd molar. For example, lower right 2nd premolar is numbered 406. Deciduous teeth are numbered similarly but the dental arcades are numbered 500 (upper right), 600 (upper left), 700 (lower left) and 800 (lower right) (Fig. 1).

*Note: some authors do not consider mesial and distal to be appropriate terms in equids due to the lack of a complete dental arch in these species; however, the American Veterinary Dental College considers the terms appropriate while recognizing that most veterinary species lack a complete dental arch.

3. Equine Oral Structural Anatomy

Equine teeth are similar to teeth of other domestic animal species and humans as they are all composed of pulp, dentin, enamel, and cementum. Horses, however, are unique in that all three of the mineralized dental tissues (cementum, enamel, and dentin) are exposed on the clinical crown of a tooth in wear, whereas only enamel is exposed on the normal brachydont tooth.

The pulp is the most interior portion of the tooth and is composed of veins, arteries, lymphatics, nerve fibers, connective tissue, and undifferentiated stem cells. The pulp is the “heart and brain” of the
tooth as it is the connection of the tooth to the head through the nervous and circulatory systems. The pulp system in the horse is composed of individual pulp horns connected to a common pulp chamber near the roots. One or more root canals then traverse the roots and exit at the apical foramen or apex (Fig. 2). The pulp comprises a large percentage of the volume of a tooth, and is surrounded only by a thin shell of mineralized tissues in the young horse. The number of pulp horns per tooth remains constant though their height and diameter decreases with age due to the deposition of secondary dentin. Incisors, canines, and first premolar teeth have a single pulp horn although the pulp horns of incisors can sometimes be divided into two horns occlusally due to a prominent infundibulum.1 The third and fourth premolars (Triadan 07 and 08) and first and second molars (Triadan 09 and 10) each have five pulp horns, the second premolars (Triadan 06) and mandibular third molars (Triadan 311 and 411) have six pulp horns, and the maxillary third molars (Triadan 111 and 211) have six or seven pulp horns.7,8 (Fig. 3) Counting the incisors and cheek teeth arcades, a typical horse has at least 140 pulp horns potentially vulnerable to damage. In a recent study, two thirds of horses over 15 years still had teeth with an open apex and all horses in this study, including horses up to 27 years of age, had persistent root canals despite an apparently “closed” apex in all horses greater than 23 years of age.9 In contrast, the apices of the teeth of cats and dogs have been found to be radiographically “closed” by 10–11 months of age in most cases.10,11 The open apex leads to a better blood supply to the equine tooth for a longer period of time, which might allow for a better reparative response to trauma.

The pulp serves as a nutrient delivery system for the tooth to support the physiologic and reparative functions of the odontoblasts, a sensory organ to detect external stimuli, and as an immune center for the recognition and processing of antigens.12 When existing odontoblasts are damaged, undifferentiated stem cells in the pulp give rise to new odontoblasts, which aid in repair of a tooth by the deposition of tertiary dentin.6 Because the pulp system is immediately surrounded by odontoblasts and both tissues are derived from the same embryologic stem cells, this duo of dental components is often referred to as the dentin-pulp complex. Although a tooth has a viable pulp, it is a living structure that has the capability of constant change through normal physiologic processes or in response to external stimuli.

Dental hard tissues (dentin, enamel, and cementum) surround the pulp and are arranged in a layered manner (Fig. 4). Odontoblasts produce dentin...
in a centripetal manner throughout the life of a tooth, gradually decreasing the height and diameter of the pulp horns. There are four major types of dentin in the equine tooth: primary dentin, regular secondary dentin, irregular secondary dentin, and tertiary dentin. In addition, there is a very thin layer of an unmineralized dentin matrix termed predentin between the mineralized dentin and the odontoblasts. The mineralization of the predentin layer occurs at approximately the same rate as the production of new predentin. Primary dentin is produced during the initial development of the tooth. Production of primary dentin ceases around the time period that the tooth erupts through the gingiva. Regular secondary dentin is produced peripheral to the pulp horns from this point onward as a normal, physiological process and is, morphologically, an extension of primary dentin. Deposition of irregular secondary dentin is also a physiological process. It is produced similarly to regular secondary dentin but is found subocclusally near the tip of each pulp horn. Irregular secondary dentin has fewer tubules so is less porous than regular secondary dentin, an additional mechanism to protect the pulp from damage due to tooth attrition. In contrast, tertiary dentin is not physiologic. Damaged odontoblasts or replacement cells from the pulp produce tertiary dentin in an attempt to protect the pulp system in response to restorative dental procedures, caries, or trauma to the tooth. If trauma to a tooth is severe enough to damage it beyond what tertiary dentin deposition can repair, the irreversible pulpitis can result in death of the odontoblasts. Death of the odontoblasts results in cessation of production of secondary dentin. This can be seen clinically on radiographs of incisors or canine teeth in which one of a pair of complementary teeth has a wider pulp horn indicating that production of dentin had ceased in that tooth at some point in the past. Radiographic evaluation of individual pulp horns in a cheek tooth is usually not possible due to superimposition of the pulp horns and enamel folds within the tooth. However, differences in pulp horn diameter indicative of pulpitis or pulp necrosis can be observed with computed tomography or magnetic resonance imaging of diseased teeth, although these modalities are infrequently used clinically to detect early pulp disease (Fig. 5).

Odontoblast cell bodies extend finger-like processes through tubules that extend peripherally to the amelodentinal junction (Fig. 6). The dentinal tubules in the horse are covered peripherally by enamel throughout the length of the clinical and reserve crown. The role of the odontoblast processes and tubules in the equine tooth is not certain although they are likely involved in transport of nutrients through the dentin as well as transmission of external stimuli to nerves in the pulp.

Dentin is more mineralized (70%) than cementum (60%) but less than enamel (96–98%). Dentin therefore wears more quickly than enamel, contributing to the “rough” occlusal surface important for grinding fibrous feed material. Secondary dentin is recognizable on the occlusal surface of a tooth due to its tendency to be a dark brown color from the uptake of plant pigments. A “smear layer” of ground, calcified tooth material normally protects the dentinal tubules exposed to the occlusal surface decreasing the permeability of the dentin to substances and bacteria that might otherwise traverse the dentinal tubules and traumatize the pulp.
Enamel is the hardest substance in the body and is the most mineralized tooth substance. Enamel is present external to the dentin in what is called the peripheral enamel ribbon. Enamel is also found in all incisors and maxillary cheek teeth as an invagination from the occlusal surface called the infundibulum (Figs. 4 and 7). The infundibulum of incisors is also referred to as the "cup" and is used as an aid in determining the approximate age of a horse. It extends apically a variable distance from the occlusal surface and will eventually disappear with normal tooth wear. Each maxillary cheek tooth has two infundibula. The infundibula form to increase the amount of enamel present on the occlusal surface to improve wear resistance of the tooth (Fig. 7). Mandibular cheek teeth lack infundibula but have extra enamel on the occlusal surface through a more extensive pattern of infolding of the peripheral enamel ribbon than is present in maxillary cheek teeth.8 (Fig. 8) Because enamel is not grossly present in the root region of teeth, once a tooth wears to this level it will wear more quickly. Similarly, once a maxillary cheek tooth wears past the infundibular enamel, the tooth will tend to "cup" out with wear given that there is no longer any enamel protecting the central portion of the tooth from wear.

Type 1 enamel predominates in the maxillary cheek teeth and Type 2 enamel predominates in the incisors.16 Mandibular cheek teeth are composed of a mixture of Type 1 and Type 2 enamel, although Type 2 predominates. Type 1 enamel prisms and interprismatic plates have a regular arrangement that is more or less perpendicular to the occlusal surface, giving it superior resistance to wear. Type 2 enamel contains prisms that are arranged more three dimensionally, giving it more resistance to fracture from shearing forces. The predominance of Type 1 vs Type 2 enamel in the maxillary cheek teeth and incisors, respectively, and a blend of Type 1 and Type 2 enamel in mandibular cheek teeth gives each type of tooth the best structure for its intended function.16 Enamel is the only one of the trio of dental hard tissues that has no capacity to regenerate.

Enamel, because of its hardness, wears more slowly than dentin and so represents the "ridges," as opposed to the dentinal "valleys," on the occlusal surface of the tooth. The resulting roughness of the occlusal surface facilitates grinding of feed material, particularly forages. If the occlusal surface of a cheek teeth arcade were smooth, which can occur iatrogenically through odontoplasty that is too aggressive, the opposing teeth can no longer properly process forage until some degree of "roughness" of the occlusal surface is restored through dentinal wear. Enamel is very brittle due to its high mineral content. However, it is protected in much the same manner as safety glass in a vehicle windshield given that the peripheral enamel ribbon is sandwiched between dentin internally and cementum externally.

Cementum is found external to the enamel, peripherally, and is a hard-tissue histologically similar to bone that serves as an attachment point by which the periodontal ligament anchors a tooth to the dental alveolus or socket. Cementum is also the substance that fills the infundibulum of incisors and maxillary cheek teeth. A study of cemental filling in the maxillary cheek teeth found that 22% of the infundibula examined exhibited some degree of cemental hypoplasia, 65.7% had cemental caries or other defects and that only 11.7% of infundibula were completely filled with normal cementum.17 Infundibular cemental hypoplasia and other defects leave a void in the tooth that can pack with feed material which subsequently may undergo bacterial fermentation. This process leads to progressive demineralization of the inorganic dental tissues.18 Mild-to-moderate infundibular caries that may or may not destroy the infundibular enamel can predispose an affected tooth to fracture. Severe infundibular caries can progress through the infundibular enamel to the dentin, exposing dentinal tubules and causing a near-pulp exposure, or can erode completely through the dentin to the pulp.
causing a direct pulp exposure (endodontic disease). As in brachydont species, cementum covers the root of the tooth, but in equids, cementum also covers both the reserve crown and clinical crown unless worn off through attrition. In fact, additional cementum is produced immediately subgingivally, except on the interproximal faces, given that the tooth continually erupts so that the cementum layer is thicker around the clinical or erupted crown.19 Cementum has the capacity for regeneration and can be deposited in excess (hypercementosis) in response to external stimuli (e.g., apical periodontitis or equine odontoclastic tooth resorption and hypercementosis).

The periodontium consists of the components that anchor a tooth into the bone of the jaws. The periodontium is made up of the alveolar bone, periodontal ligament, gingiva, and cementum. Because the cementum is histologically similar to bone, it makes sense that the periodontal ligament attaches alveolar bone to “bone” (cementum). The periodontal ligament is made up of fibers that attach at various angles and make the tooth resistant to many forces including vertical extrusion forces such as those commonly applied during tooth extraction. The periodontal ligament also becomes more organized apically as a horse ages such that geriatric teeth with a decreased reserve crown are supported by a stronger periodontal ligament attachment making the root tips more difficult to extract.20 Structurally, the periodontal ligament has a network of blood vessels within three specific arrangements with collagen fibers that respond to differing forces during mastication: 1) to help maintain blood flow despite masticatory stresses, 2) to resist mechanical traction forces, and 3) to provide a hemodynamic cushion to process compression forces.21 In addition, due to their hypsodont nature, the periodontal ligament of equids must constantly remodel to allow for continued eruption of the reserve crown.

The periodontal ligament is protected coronally by the gingiva. Gingiva is specialized tissue that surrounds each tooth. Although it has a free edge that makes up the external border of the gingival sulcus, gingiva is firmly attached to the tooth through an epithelial attachment at the apical aspect of the sulcus, which limits access of bacteria deeper along the tooth. In addition to the gingival attachment to the tooth, the gingival sulcus is bathed with gingival crevicular fluid that contains leukocytes and immune mediators that also help prevent bacterial infection.1 When this dentogingival attachment is breached and bacteria reach the deeper tissues, tissue destruction known as periodontal disease results.

Equine teeth differ from the brachydont teeth of dogs, cats, and humans in that they are considered radicular hypsodont in nature.4 This means they form true roots, and most equine teeth, with the exception of the first premolars, continue to erupt throughout a finite lifetime. A cheek tooth in the horse has no root development at the time of eruption. The tooth continues to lengthen for approximately 1–2 years after eruption after which time there is no net length gain of the tooth and the tooth actually shortens due to eruption and occlusal wear. Equine teeth wear at an average rate of 2–3 mm/year but have been found to erupt up to 9 mm/year in some younger horses.1 Enamel production occurs in cheek teeth until approximately 5 years post-eruption. Formation of true roots through production of cementum and dentin continues for approximately 10 years post-eruption.1 Once enamel production is completed, ameloblasts disintegrate and there is no capability for repair of enamel for the rest of the life of the tooth.22 Equine incisors tend to elongate for a slightly longer period of time, increasing in length for 2–4 years post-eruption then maintaining that length despite continuing wear for another 13–15 years. After that time they will gradually decrease in length due to wear at the occlusal surface.23 Because of the hypsodont nature of equine teeth, with continued eruption they are vulnerable to wear or eruption abnormalities that can interfere with proper mastication. Enamel insufficiency on an antagonistic tooth, absence of an antagonistic tooth due to developmental reasons or extraction, or maleruption of a tooth can result in abnormal wear patterns, resulting in the development of a Class 1 malocclusion.24 On a positive note, due to this same hypsodont nature of the teeth, the periodontal ligament is continuously remodeling to facilitate eruption of the reserve crown for continual replacement of the chewing surface as it is worn. This process makes it possible for periodontal disease to be clinically improved through nonsurgical means in the horse if detected before it is too advanced.

4. Equine Oral Functional Anatomy

Equine teeth are classified into four groups: incisors, canine teeth, premolars, and molars. Horses have a diphyodont dentition. This means they have both a deciduous and a permanent component of teeth at different stages of their life.4 Horses have a complement of 24 deciduous teeth and 36–44 permanent teeth. Incisors and premolars 2, 3, and 4 (Triadan 06 to 08) have deciduous precursors whereas molars do not. The 12 incisors are considered the “nipping” teeth that function during grazing to sever the stems and leaves from pasture forage plants. Because horses have both maxillary and mandibular incisors compared with cattle that only have mandibular incisors that contact a maxillary dental pad, they are very efficient at grazing grasses close to the crown of the plant.

Canine teeth, up to four total, are more common in male horses but are often present as rudimentary versions in mares. Interestingly, in 1895, Goodall remarked that “small deciduous canines are always present in both sexes, but they are absorbed without eruption.”25 Canine teeth are considered to be fight-
ing teeth and do not really participate in mastication given that they do not make occlusal contact with any other teeth. Although canine teeth do continue to erupt and remodel like other hypsodont teeth, these processes occur at an extremely slow rate. Although in the past it has been recommended to reduce the canine tooth height, removal of the peripheral enamel layer may expose dentinal tubules that can lead to an indirect pulp exposure. Direct pulp exposure with crown reduction is also a distinct possibility given that the level of the pulp horn of a canine tooth cannot be determined clinically or based on age.

Premolars and molars have the same tooth form and are referred to as the cheek teeth. The exception is the first premolar (Triadan 05), also known as the wolf tooth. First premolars are variably present and more likely to be present in the maxillary arcades. Like the canine teeth, they do not participate in mastication. Premolars 2–4 and the three molars, six teeth in each of four arcades, are packed together to function as a single grinding unit. Three dimensionally, there are a few important features of the cheek teeth to consider when examining the equine oral cavity. Horses exhibit anisognathism, which means the maxillary cheek teeth component is wider than the mandibular cheek teeth component. In addition, based upon measurements by Merillat, maxillary cheek teeth themselves are approximately 40% wider than the opposing mandibular cheek teeth26 (Fig. 9). These features are important because they highlight the need for a full lateral excursion to ensure even wear of the opposing cheek tooth surfaces. Cheek-teeth arcades often have an occlusal surface that is not planar but has a curvature in a vertical dimension such that the distal mandibular teeth can seem to be elongated. This curvature is termed the “Curve of Spee” and is very pronounced in Arabian horses (Fig. 10). Horses with an exaggerated Curve of Spee can falsely seem to have large hooks of their mandibular 11s. In a horizontal dimension, mandibular arcades are relatively straight from mesial to distal whereas the maxillary arcades tend to be positioned in a slight arc with the distal one or two maxillary cheek teeth curving medially enough to make them more difficult to access during odontoplasty procedures (Fig. 11). The cheek-teeth arcades also have an angulation of their occlusal surfaces dorsally in a vestibular to lingual/palatal direction that was traditionally thought to be between 10 and 15 degrees. A recent study including both normal and pathological arcades showed that the mean maxillary cheek teeth occlusal angle ranges from 12.5–18° with the steeper angles more mesially in the arcade.27 The mean mandibular cheek teeth occlusal angle ranged from 19.2–30° with the steeper angles more distally in the arcade.27 Therefore, these angles should not suggest treatment goals, only that occlusal angulation is a normal feature of the cheek teeth within certain ranges. Extremely steep angles such as are found

Fig. 9. Anisognathism and disparity in widths of individual maxillary (blue line) vs mandibular (red line) cheek teeth.

Fig. 10. Curve of Spee. The red line indicates curvature of the arcade and the yellow line indicates an imaginary flat occlusal plane.

Fig. 11. The red arc indicates the medial curvature of the distal cheek teeth. The blue lines demonstrate the nonparallel nature of the interproximal spaces.
in a condition called shear mouth as well as iatrogenically induced flat table surfaces may interfere with mastication.

An additional feature of cheek teeth is the non-parallel nature of the interproximal spaces (Fig. 11). This should be taken into account during burring of the interproximal spaces for pathologic diastema treatment or application of a tooth spreader during tooth extraction because working outside of the interproximal space will result in damage to the teeth. Each maxillary cheek tooth has two prominent vertical ridges on its vestibular aspect called cingula (Fig. 12). The cingula are formed by enamel outfoldings and are the location of the so-called enamel points that are smoothed during odontoplasty or floating procedures. Note the close proximity of the vestibular pulp horns to the cingula, a fact that should be taken into account during odontoplasty of the sharp enamel points to avoid pulp exposure on the vestibular aspect of a maxillary cheek tooth. Transverse ridges on the occlusal surface, one to three per tooth, are another morphologic feature of cheek teeth.5 (Fig. 13) They may have a role in guiding the medial movement of the cheek teeth during the power stroke phase of mastication or may increase the surface area for mastication but this has not been studied.

The timing and pattern of eruption of both the deciduous teeth and the permanent teeth are very important to dental function. Additional cheek teeth erupt as the jaws elongate with growth so that the mouth is functionally "full" of teeth as a horse ages until all teeth are erupted by approximately 5 years of age. A foal will erupt three deciduous premolars in each arcade that will be replaced over time with the three permanent premolars. Three molars will also erupt to complete the full complement of six cheek teeth in each arcade. The cheek teeth erupt in a staggered fashion with the last permanent tooth to erupt, the 4th premolar (Triadan 08, also known as the 3rd cheek tooth), erupting between the 3rd premolar (Triadan 07) and the 1st molar (Triadan 09) (Fig. 14). This pattern of eruption serves to pack the six cheek teeth in each arcade into a single functional grinding unit.

All of the equine incisors have both deciduous and permanent components. Maleruptions are fairly common in the incisor arcades. The incisors erupt in order from mesial to distal and are not packed as an arcade in the same manner as the cheek teeth. If a deciduous incisor does not exfoliate at the proper time, it is common for the permanent tooth to erupt lingual/palatal to its deciduous component (Fig. 15). This can result in a failure of the opposing incisors to occlude. When exfoliation and eruption of the incisors occurs “properly,” the four incisor arcades function together as two units, a maxillary component and a mandibular component.

The maxillary teeth are fixed within the maxilla and incisive bones. The mandibular cheek teeth are fixed within the paired mandibles that are fused together at the mandibular symphysis. The mandibles articulate with the rest of the skull at the temporomandibular joints (TMJ). The TMJs are

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**Fig. 12.** The yellow arrows point to the cingula and the red lines indicate the vestibular (buccal) pulp horns.

**Fig. 13.** Prominent transverse ridges are present on the maxillary (yellow arrows) and mandibular (red arrows) arcades of this skull specimen. Photo courtesy of Dr. Dennis Rach.

**Fig. 14.** Timing and pattern of eruption of cheek teeth.
unique joints in that they allow for both pivoting and translational movements. In the resting or centric incisor position, the incisors are loaded and the cheek teeth are separated (Fig. 16). The translational movements come into play in the process of mastication as the mandibles descend ventrally (opening stroke) and then laterally and dorsally to one side until cheek teeth contact (closing stroke). Finally, the mandibles move back toward the incisor centric position (power stroke) to complete one chewing cycle (Fig. 17). The power stroke phase of mastication is the phase during which the actual grinding of feedstuffs takes place. There is actually movement in all three dimensions as there is also some movement in a rostrocaudal direction during the process of mastication. In the “normal” horse, when the incisors are in contact in the centric or resting position, the cheek teeth are not in contact occlusally due to a separation between the maxillary and mandibular arcades and, in addition, are also separated in a mediolateral dimension due to the anisognathic nature of the horse’s jaws. In contrast, during mastication, when the active mandible has moved laterally then closed to allow cheek tooth contact on that side, the incisors will be separated in a vertical dimension. In this manner, the dental apparatus of the horse can perform two functions, nipping and grinding, although at different times.

Another interesting observation regarding the three dimensional arrangement of the cheek teeth, incisors, and TMJs is the fact that an imaginary line extending along the incisor occlusal tables caudally
usually transects the TMJ (Fig. 18). This should prompt a clinician to make sure to maintain this incisor occlusal table relationship to the TMJ in the event that occlusal odontoplasty of the incisors is deemed necessary. Interestingly, the cheek teeth tables are on an entirely different plane than either the incisors or TMJs. These factors are likely biomechanically related to the function of incisors vs the cheek teeth.

The last pieces of the masticatory puzzle are the cheeks, tongue, and palate. The cheeks function to maintain a food bolus between the cheek teeth arcades or more medially. The tongue, working in conjunction with the staggered folds of the palate (Fig. 19) functions as an auger system to transport the feed bolus toward the pharynx for swallowing. Although these soft tissues are not usually considered as part of the dental apparatus, they are intimately associated with the teeth and are prone to injury by sharp dental projections. Pain resulting from this soft tissue trauma can affect the ability of the horse to efficiently acquire, process, and transport feed materials.

5. Clinical Relevance

The pulp system of a young horse comprises a large percentage of the volume of each tooth. As odon- blasts produce secondary dentin in a centrifugal manner, each individual pulp horn decreases in diameter and height. To complicate this process however, due to the hypsodont nature of the tooth, the tooth is continuing to erupt while the occlusal surface of the tooth is being worn down. As long as deposition of secondary dentin at the occlusal end of the pulp horn occurs at a rate that equals or exceeds that of wear, opening of the pulp horn should not occur with normal attrition. However, a pulp horn can inadvertently be violated during removal of dental hard tissue in an odontoplasty procedure as well as by fracture of a tooth. Recent work has shown that the thickness of subocclusal secondary dentin varies greatly among horses and even between pulp horns within a normal individual cheek tooth. Subocclusal secondary dentin thickness in elongated cheek teeth was found to be extremely variable, from 1.87–36.02 mm with a mean of 12.14 mm. Because it is nearly impossible to determine the depth of a pulp horn below the occlusal surface of a tooth in a horse without the use of advanced imaging such as computed tomography, one must be very careful when reducing the height of any tooth. Pulp horn distance from the nearest interproximal space has also been assessed and it was determined that some were as close as 1.3 mm with a mean of 5.75 mm, and 5.3% of pulps were found to be within 3.5 mm of an interproximal space in this same study. A pulp horn does not have to be directly opened to cause damage. An indirect pulp exposure can occur through exposure of dentinal tubules that still communicate with the pulp.

Pulpitis can be induced in a tooth with injudicious use of dental burs. Overheating can occur with dull burs, working for too long on a single tooth, or failing to properly cool the tooth. Histologic studies examining the effect of tooth temperature changes on the pulp using macaque monkeys as a model have shown that a 5.5°C increase in tooth temperature causes destruction of the odontoblasts in the region of the thermal insult. Interestingly, similar teeth examined 56 days after thermal insult showed histologic evidence of successful recovery from the trauma. This demonstrates the ability of teeth to undergo repair and survive despite significant injury. In horses, it is not known at what temperature pulp change occurs, but studies have shown increases in pulp temperature in isolated horse teeth after short periods of grinding. One study demonstrated a 4.62°C temperature increase in a tooth from a 6-year-old horse after only 20 seconds of grinding with a high-speed die grinder. Also of importance, it was noted that the teeth did not cool back to normal temperature for 5 to 10 minutes after this 20 seconds of grinding. However, when constantly water-cooled burs were used or intermittent irrigation was provided, tooth temperatures did not increase more than 2.64°C, a temperature not associated with histologic damage to the pulp in the macaque study.

When considering the cheek teeth as grinding surfaces, we think about the 24 teeth being composed of 12 pairs of teeth making occlusal contact. If any of these pairs of teeth are taken out of occlusion either iatrogenically or by natural processes such as maleruption or malocclusion, the efficiency of mastication decreases. In extreme instances, such as a wave complex in an older horse, the planes of occlusal

Fig. 19. Staggered palatal folds indicated by yellow and red arrows.
6. Conclusions

- The three-dimensional anatomy of the pulp system of an equine tooth and its likely proximity to the tooth margins should be considered before a clinician performs odontoplasty procedures to avoid causing irreparable damage. Treatment of large occlusal elongations may require staged reductions to allow time for deposition of secondary or tertiary dentin between procedures to avoid pulp exposure.

- The nature of a canine tooth (Triadan 04) should be considered before performing crown reduction because removal of the peripheral enamel exposes dentinal tubules and can result in a secondary pulp exposure.

- The relationship of enamel and dentin and their relative wear resistance is important because the occlusal surface of cheek teeth must be rough to facilitate efficient mastication of fibrous feed material.

- Because periodontal disease is so destructive and painful, a clinician should understand the structure and function of the gingival attachment in protecting the periodontal ligament to guide periodontal disease preventative and treatment measures.

- The complexity of the periodontal ligament and its role in the support of a tooth should be considered when performing dental extractions.

- Due to the order of eruption of teeth to promote packing of an arcade, young horses should be examined frequently to facilitate early detection of eruption problems.

- Equine teeth maintain a good blood supply to their teeth for a longer time than those of many other species, so care must be taken to not overheat teeth and inadvertently damage the pulp.

Equine dentistry, including teeth floating, has been practiced for centuries. Advancements in technology have allowed a better understanding of a horse’s mouth and how it functions. Dentistry is an important component of the health care of a horse. A veterinarian must understand the structure of the teeth and how and why they are arranged the way they are before removing dental hard tissue to avoid causing damage to the teeth or causing functional changes in the mouth. Much research is still needed to further unravel mysteries of the anatomy and physiology of the equine oral cavity.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References


How to Perform an Equine Oral Examination

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1. Introduction
Many of us were taught in veterinary school to float teeth, never giving a thought to a proper oral examination. Clients call requesting a dental float without even considering the importance of examination. Now it is inappropriate to perform a dental treatment (floating) without a proper dental examination. An oral evaluation can be broken down into four main components. The first component includes the orthodontic examination to determine whether the teeth are in proper alignment and if there are any dental overgrowths due to misalignment. Second is the periodontal examination to determine pathology of the periodontal ligament, gingival, and alveolar bone. Third is the endodontic examination to detect pathology of the dental pulp. Lastly, an examination of the oral soft tissues is performed to determine pathology of the cheek, palate, and tongue including trauma and neoplasia. These examinations can occur individually or concurrently but should be performed in a consistent order to minimize pathology being overlooked.

2. Materials and Methods
Using minimal, inexpensive equipment and simple examination techniques, the equine practitioner can recognize dental disease and inform owners of treatment options. The oral examination should be performed in a safe environment for the horse and practitioner. This may be in a stall, wash stall, or stock. The footing should be level and not slippery. There should be little backlight behind the horse and shining toward the practitioner, which makes it difficult to illuminate the oral cavity with a headlamp. The equipment needed for a proper dental examination in the horse includes a full-mouth speculum, bright light source (headlamp), dental mirror, dental explorer (Shepherd’s hook), and periodontal probe (Fig. 1). Each instrument should have a handle long enough, usually 19 inches, for the working end to reach the third molar. Standard-sized, human, periodontal probes and explorers may be used for the incisors and canine teeth. The working end of periodontal probes should be thin and have grooved markings for measuring pocket depth. For a more complete diagnosis of endodontic and periodontal disease, dental radiography is necessary.

Prior to sedation, perform a general examination to ensure there are no cardiovascular conditions that would make the patient unfit for sedation. Next, perform an extra-oral examination of the patient’s head. This portion of the examination includes palpating the temporomandibular joint, the upper and lower jaws, and just ventral to the facial crest along the buccal surface of the upper cheek teeth. Swellings, draining tracts, or areas that are painful should be noted for further investigation.
To perform the oral examination, sedate the patient using methods for standing restraint and rest the patient’s head in a dental halter or head stand. The incisors are examined prior to the placement of a full-mouth speculum. Part the lips and observe the upper and lower incisors as well as the canines on the labial, lingual, proximal, and occlusal surfaces. Normal alignment of the upper and lower incisors is when they are contacting each other in occlusion and are level on the horizontal plane with the midline of the upper incisors directly opposing the midline of the lower incisors. Note any deviations from the normal alignment as well as diagonal, ventral, or dorsal curvatures of the incisors. These misalignments are often due to uneven jaw growth during development and may or may not require dental therapy. When the incisors are observed from the lateral view, the upper incisors should be in occlusal contact with the lower incisors. A misalignment in which the lower jaw is shorter than the upper jaw, thus causing the upper incisors to rest rostral to the lower incisors is called a Class II malocclusion. This can be caused by either mandibular brachygnathism or maxillary prognathism. The opposite misalignment in which the upper jaw is shorter than the lower jaw is a Class III malocclusion. This can be caused by either mandibular prognathism or maxillary brachygnathism. The number and location of incisors are noted as well as their color, mobility, and surface texture. The dental explorer is designed to be used above the gingival margin by drawing the point of the instrument over the tooth surface. Normal dental tissues should be hard and smooth and the explorer will glide across the surface of the tooth. Defects in the cementum, enamel or dentin may be seen visually or felt as soft, “sticky” areas when a dental explorer is drawn over the defect. The gingiva, mucosa, and adjacent soft tissues should also be examined. The gingiva surrounding the incisors should be light pink, smooth, and even along the vestibular margin (Figs. 2 and 3). A periodontal probe is gently introduced into the gingival sulcus at multiple locations around each tooth to identify periodontal pockets. Gingival sulcal depths of less than 5 mm are clinically acceptable.1

Inspect the occlusal surfaces of the upper and lower incisors both visually and with the dental explorer. Use a 6-in. dental explorer to examine
the incisors and canines. Special attention should be employed with the dental explorer to the brown stained area of secondary dentin that sits labial to the infundibulum. Normal dentin is smooth. If the explorer sticks into the dentin or drops into the pulp cavity, this may suggest a pulp defect. All incisor and canine crown fractures should be examined with a dental explorer to determine whether a pulp exposure has occurred. A discolored tooth (excluding stained cementum) has suffered pulp injury (Fig. 4). Tooth fractures, pulp defects, and discolored teeth should be radiographed to make a diagnosis and offer a treatment plan.

Examine the gingiva surrounding the incisors for gingival recession and draining tracts (Fig. 5). Draining sinus tracts from abscessed incisor teeth appear like papules at the mucogingival margin. When an incisor or canine tooth abscesses, the sinus tract typically drains intraorally, either at the mucogingival margin near the infected tooth appearing like a small papule (Fig. 5) or along the periodontal ligament.

Before using the oral speculum to look at the cheek teeth, place a cheek retractor in the commissure of the lip and look in the vestibule on the left and right side alongside the cheek teeth to observe the space between the upper and lower cheek teeth (Fig. 6). Shift the mandibular incisors left and right and observe the point of molar contact of the cheek teeth. This view along the space between the cheek teeth reveals overgrown teeth and where there is premature contact during the chewing cycle. Lateral excursion of the mandible can be examined by moving the lower jaw to the left and right to the point where the cheek teeth contact and separate the upper and lower incisors while the head is resting in a dental halter or stand. The excursion to molar contact can be measured by comparing the location of midline of the lower incisors in relation to the upper incisors when the cheek teeth come in contact and cause the incisors to part. Observing the point of cheek teeth contact identifies the cheek

Fig. 4. This upper, first incisor (tooth 101) is discolored (gray/black) and has gingival recession (the gingival margin is recessed apically compared with the gingival margin of the neighboring teeth). This is an indication for taking radiographs of this tooth. This tooth was found to be necrotic and required endodontic therapy.

Fig. 5. Gingival recession and a draining tract can be observed at the mucogingival junction of this lower right second incisor (tooth 402). This is an indication for dental radiography to determine a diagnosis and to make a treatment plan.

Fig. 6. A cheek retractor and bright light source are used to view the point of cheek teeth occlusion and to determine cheek teeth overgrowths that may cause premature contact during mastication.
tooth overgrowths that are making premature occlusal contact that should be reduced. A second objective measurement of mandibular motion during occlusion is the rostral-caudal mobility. During the chewing cycle, the lateral pterygoid muscle contracts causing a slight rostral-to-caudal motion of the mandible. This motion can be duplicated passively in the sedated horse by comparing the relative positions of the upper and lower incisors when the head is held in a horizontal plane to when the head is held vertically. When the neck is flexed 90° at the poll, the mandible will move rostrally in relation to the maxilla. A measurement is made comparing the difference between the labial surface of the upper and lower first incisors when the head is held in a horizontal plane vs the difference when the head is flexed 90° at the poll. Failure of the mandible to move rostrally may suggest dental interlock, which is occlusal interference due to overgrown cheek teeth that prevents normal range of mandibular motion during mastication.\(^4\) Rostral-caudal mobility has been found to increase after floating and occlusal correction of dental overgrowths.\(^5\)

To examine the cheek teeth, place a full-mouth speculum in the horse's mouth. Examine the cheek teeth in a systematic fashion, looking for sharp enamel points that may be lacerating the cheeks or tongue. Examine the occlusal surface for dental overgrowths such as hooks, waves, steps, and excessive transverse ridges (Fig. 7). Overgrowths may occur due to misalignment of cheek teeth or to pathology in the opposing arcade (e.g., a fractured tooth, a dysplastic tooth that did not develop normally, an age tooth with no infundibular enamel, a missing tooth, or a widened interproximal space). These pathologic conditions will lead to steps or excessive transverse ridges in the opposite arcade. The elongated tooth is a normal tooth that is not sufficiently worn by the opposing tooth during mastication.

The interproximal spaces between teeth are examined for separations called pathologic diastema where foodstuffs lodge and cause periodontal disease. Food must be cleaned from the space with long-handled Gracey curettes and lavage. After cleaning the interproximal space of food material, tartar, and plaque, use a periodontal probe to measure gingival recession and depth of pocketing to determine the amount of periodontal attachment loss. Examine the occlusal surface of each maxillary and mandibular cheek tooth using a dental mirror and dental explorer. Look for fractures, pulp exposures, and cavities. Feel for defects in the occlusal surface by pulling the sharp point of a long equine dental explorer over the occlusal surface of the tooth. The brown stained areas on the occlusal surface are secondary dentin that was laid down in each of the retreating pulp horns. A clinician should carefully explore these areas for pulp defects (Fig. 8). Infundibula should be assessed for decay and care must be taken not to mistake the vascular channels in the center of the two maxillary cheek teeth infundibula as pulp defects. The practitioner should note if the decay involves the central cementum only, cementum and enamel or if it extends past the infundibular enamel into the dentin. Additional signs of endodontic disease in the maxillary cheek teeth are draining tracts or nasal discharge that is typically unilateral. Swellings or draining tracts that develop along the ventral border of the mandible may be an indication of dental disease in the mandibular cheek teeth. After examining all the cheek teeth and the interproximal spaces with a
dental mirror, periodontal probe, and dental explorer, also examine the oral soft tissues. Use a dental mirror and cheek teeth retractor to examine the cheek and hard palate. Move the tongue side to side to examine the sublingual portion of the oral cavity. Look for lacerations caused by sharp enamel points, foreign bodies embedded in the cheek or tongue, and soft tissue lumps and growths that may need biopsied. Record all of the examination findings, radiographic interpretations, treatments, and prognoses in a dental record or medical chart.

Proper diagnosis and treatment of dental disease necessitates a complete oral examination and the identification of pathology such as elongated teeth, discolored teeth, draining tracts, pulp defects, cavities, fractures, feed impactions, periodontal pocketing, and soft tissue lesions. A thorough oral examination with ancillary testing such as radiography leads to a complete diagnosis so that a treatment plan and a prognosis can be established. Treatment will decrease patient pain and improve the health of our equine patients.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

How to Digitally Document a Dental Examination

Stephen S. Galloway, DVM

1. Introduction

The Dental Chart

Dental charting is the process of recording the state of health or disease of the teeth and oral cavity, and it is an integral part of the examination, diagnosis, treatment, and monitoring of dental cases. Given that training, in general medicine and surgery, is prerequisite to the practice of veterinary dentistry, most veterinarians also include pertinent regional and systemic examination findings and diagnoses on the dental chart.

The dental chart is a permanent record of a patient’s dental care. Completion of a dental chart is the minimum standard of care for documenting any professional dental procedure.

In addition to providing legal documentation of the procedure performed, the dental chart assists the practitioner in providing a consistent, comprehensive examination, facilitates accurate treatment planning and fee estimation, and facilitates communication with colleagues and clients.

Although most small-animal and human dentists prefer a two-chart system (one chart for recording examination findings, diagnoses, and proposed treatment planning and a second chart for recording the treatment performed), most equine veterinarians use a combined report for both the examination and treatments. The most commonly accepted chart format is an anatomical dental diagram supplemented by brief descriptions to clarify the examination findings, diagnoses, and procedure performed. Numerous acceptable equine dental charts are available free of charge through colleagues and on the Internet. The author uses different dental charts for primary dental care and advanced procedures (endodontics, oral surgery, etc.) and recommends that veterinarians develop dental charts that meet their specific clinical caseload. Given that equine dentistry is rapidly progressing, dental chart templates should be stored in a document format, such as Microsoft Word, which allows for easy editing as a veterinarian’s dental practice changes.

Standardized Terminology and Abbreviations

To properly document any dental procedure, to communicate with colleagues, and to advance dental science, practitioners must have a working knowledge of dental terminology. An extensive glossary of terms can be found in many veterinary dental textbooks. Also, to facilitate scientific communication between colleagues, the Nomenclature Committee of the American Veterinary Dental College (AVDC) reviews, clarifies, and recommends terminology for dental and oral anatomical locations, pathologies, diagnoses, and treatments. To simplify dental charting, the AVDC recommends a list of

NOTES
abbreviations for dental nomenclature. The AVDC Nomenclature and Abbreviations are available on the AVDC website.²,³

Although various systems for describing and numbering teeth are recognized, the Modified Triadan Tooth Numbering System is the tooth-identification system of choice in veterinary dentistry.⁴ This system is applicable to most domestic animal species and provides accurate tooth identification in both written and oral communication. Similarly, the duToit Endodontic Numbering System is the system of choice for the identification of the pulp horns in equine cheek teeth.⁵ Both of these numbering systems are described in detail in the accompanying lecture on anatomy.

Although each practitioner’s dental charts may be personalized to meet his/her specific needs, the author encourages veterinarians to complete their dental records using the four standardized systems listed above to minimize confusion between colleagues. Veterinarians electing to use nonstandardized nomenclature and abbreviations should include a legend in their dental record.

The required legal content of healthcare records,⁶ and the process of dental charting have been previously described in other publications⁷,⁸; therefore, the purpose of this presentation is to describe how the use of digital technology can improve the speed, accuracy, and communication of dental records compared with written documentation.

2. Materials and Methods

Digital Records

Advances in and the affordability of handheld, touch-screen, WiFi-enabled, tablet devices and software applications offer improved recordkeeping capabilities for both the clinic-bound and ambulatory veterinarian. Tablet note-taking and drawing applications, such as GoodNotes⁹ and Graphic⁹, are available, which allow the importation and modification of PDF templates. Similarly, several annotation applications for Android and PC platforms are available; however, the author has no familiarity with these applications. Internet file-hosting services, such as Dropbox.com⁹, allow for easy access to and sharing of documents from almost any location.

The author uses an iPad⁸ tablet and the GoodNotes application for dental recordkeeping. With this application, PDF templates are uploaded from the clinic server into a Dropbox.com account and are then imported into the GoodNotes application on the iPad (Fig. 1). Once in GoodNotes, the PDF template can be duplicated or modified by adding or deleting pages from other templates using cut/copy/paste commands. Given that the author uses different charts for different dental procedures, this template modification feature facilitates creating a case-based dental record for each individual patient (Fig. 2). Given that GoodNotes is a note-taking application, handwritten modifications (notes and illustrations) in multiple colors and highlighting are made on the dental chart template using a stylus. The “lasso” tool in GoodNotes allow handwritten notes to be selected so that they can be moved to another part of the template page, as well as copy/cut and pasted to other pages within the same template or onto another template. This feature facilitates duplication of repetitive introductory information, such as date, client information, and history, when servicing multiple patients at one location (Fig. 3). GoodNotes also has textbox and other features, with which the author has little experience.

Given that most rubber-tipped styluses wear rapidly, producing sloppy handwriting, the author recommends using a stylus with a replaceable disc tip. This stylus design produces legible writing until the disc tip is physically broken. The author uses the Musemee Notier Prime Stylus¹ which allows the tip to be stored within the stylus when not being used (Fig. 4).

Once the dental record is completed, it can be stored within the GoodNotes file folder and modified indefinitely. Modified record templates in the GoodNotes file folder can also be copied, permanently deleted, or erased (there is an Undo command) for use on another patient.

Modified records can also be exported back into Dropbox.com under a unique filename. Once a record is exported from GoodNotes into Dropbox.com, the handwritten modifications are permanently saved onto the PDF file, and the modifications cannot be changed if reimported back into GoodNotes. Although GoodNotes is specifically linked to Dropbox.com, other Internet file-hosting services are available for offsite file storage/access. Internet record storage is becoming increasingly popular within the veterinary profession, and this service can be especially time-saving to ambulatory veterinarians and veterinarians who provide after-hours emergency services. Although some practices have committed to permanent Internet storage of medical records, this author prefers to use Dropbox.com for temporary storage of the previous year’s records. An introductory Dropbox.com 2-GB account is free of charge with available promotional space upgrades and reasonable rates for business account storage. Dropbox.com is also linked to several email servers and is commonly used by veterinary professionals.

Digital Photography and Oral Endoscopy

“Pictures are worth a thousand words” and with the advances in and affordability of handheld cameras, photographic and video supplementation of the written dental record is a common practice of veterinary dental professionals. It is almost impossible for the consumer to purchase a camera or phone today that does not feature publication-quality photographic imaging capabilities. Many lesions and oral condi-
tions are difficult to describe accurately, and dental photographs optimize the recording of lesion characterization and location, support treatment planning, and improve accounting of treatments. Digital photographs and videos also provide a visual platform to facilitate communication with colleagues and clients.

Visual oral examination is the standard of care within veterinary dentistry, but due to the long and narrow anatomic configuration of the equine mouth and the limited spaces between dentition, cheeks, and tongue, adequate examination of the caudal oral cavity is difficult to achieve using traditional examination instrumentation. Oral endoscopy significantly improves a veterinarian’s ability to comprehensively examine and digitally document the equine oral cavity; however, the cost and poor image quality of the commercially available oroscopes have relegated the use of this technology to academic and referral practices. Due to the limitations of the commercially available oroscopes, Dr. Frank Schellenberger, in Germany, introduced the concept of coupling a digital Micro Four Thirds (MFT) camera, which features an interchangeable lens and captures high-quality images and high-definition (HD) video, to a rigid endoscope to create an affordable oroscope suitable for both clinic and ambulatory practice. Dr. Robert Pascoe, in England, further developed this concept by coupling an HD, WiFi-enabled MFT camera to a rigid endoscope so that the examination could be live streamed to a tablet device, using the camera’s free app, for improved viewing and remote control of the camera. Drs. Ed Earley and Allison Dotzel, in Pennsylvania, further expanded this concept by linking the oroscope system to a video monitor for group viewing in an academic/client education setting. Dr. Dotzel presented a lecture at the 2015 Veterinary Dental
Forum describing how to build this oroscope system⁹ (Fig. 5).

The equipment and procedural techniques for oral photography and oral endoscopy have been previously described in other publications.¹⁰,¹¹

3. Results
The author has digitalized all paper dental records and stored, and transported them on ambulatory calls, on an external hard drive, as well as on the clinic server for over a decade. The author has used the digital technologies described in this presentation for over 1.5 years and estimates that his personal daily document management time has been decreased by at least 1 hour. In addition, digital storage and transfer of clinic documents has significantly reduced, but not eliminated, the use of paper within the author’s dental practice. Digital recordkeeping requires that the practice implement new policy and training on document handling and storage to prevent accidental loss of records during transfer between tablets, Internet file-hosting services, clinic servers, and network stations; however, most employees are eager to use digital technologies and rapidly embrace these policies (Fig. 6).

4. Conclusion
Written documentation of professional veterinary procedures is required by both legal and ethical standards, and the dental chart is the most common format for written documentation of dental procedures. Dental photography provides the most accurate method of supplementing the written dental record, as well as providing a visual platform to improve communication with colleagues and clients. Advances in touch-screen tablets and software ap-
Applications make paper recordkeeping unnecessary and further improve the veterinarian’s speed, mobility, and communication capabilities. Recent adaptations of digital imaging systems by veterinarians in clinical practice has produced affordable oroscopic systems for ambulatory private practitioners that

Fig. 3. A dental chart template with handwritten annotations. The note-taking tool commands are displayed in the top-center of the screen. The Options menu to the top-right of the screen includes options for the final disposition of the record.

Fig. 4. The Museemee Notier Prime Stylus with a disk tip. The bottom stylus is configured for note taking, and the disc tip is stored within the shaft of the top stylus.

Fig. 5. The MFT digital oroscope system being used during a stall-side dental examination. Note that a young owner is actively participating in the examination without endangering himself by palpating the teeth of the horse.
have image quality as good as or better than any commercially available system in the veterinary dental market. Affordable digital technologies are currently available that can be used by every veterinary dental practice. These digital technologies improve patient care and advance dental science by improving examination accuracy, client communication, and scientific discourse among veterinary professionals.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnotes

†Microsoft Word, Microsoft Corporation, 1 Microsoft Way, Redmond, WA 98052.
‡The AVDC-recommended Veterinary Dental Nomenclature, updated May 2012, is available at http://www.avdc.org/nomenclature.html.
§The AVDC-recommended Abbreviations, updated March 2016, are available at http://www.avdc.org/abbreviations.pdf.
*GoodNotes, Time Based Technology Ltd, 35 Desert Willow Way, Reno, NV, 89511. The current price is $7.99 through the Apple App Store.
Autodesk Graphic 3.1, Indeo Inc., 400 Webster St, Palo Alto, CA 94301. The current price is $2.99 through the Apple App Store.
iPad, Apple Inc., 1 Infinite Loop, Cupertino, CA 95014.
How to Diagnose Class 1 Malocclusions in the Horse

Edward T. Earley, DVM, DAVDC/Eq

1. Introduction

The terms dental float, dental prophylaxis, and dental equilibration have been used to describe tooth reduction in the equine. The word float is derived from masonry in which a tool or apparatus is used to smooth or level wet plaster or cement. This term dental float has been applied to the horse when using tools to remove enamel points from the cheek teeth as well as the process of reduction of teeth with elongations such as hooks, ramps, and beaks. Dental prophylaxis is another term that has been used to describe the reduction of equine teeth to prevent or arrest disease processes.

Dental equilibration is a term that has been used to describe procedures that remove or reduce tooth structure. The term odontoplasty refers to the removal of tooth structure or adjustment of the tooth contours. Odontoplasty of equine teeth has been performed for “hundreds of years.” It is a frequently performed procedure with minimal evidence of effectiveness.

Malocclusions in the horse can be described in four categories. Normal occlusion is termed as a Class 0. Class I malocclusions involve horses with normal jaw length of the maxilla and mandibles. However, the teeth are either shifted, tipped, rotated, overlong, or short. Classes II, III, and IV are described in Table 2.

Odontoplasty of equine teeth has been performed on horses for “hundreds of years.” It is a frequently performed procedure with minimal evidence of effectiveness.

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plasty in the equine patient. A literature search was performed for scientific articles on the topics of “Equine/Horse dental equilibration,” or “Equine/Horse odontoplasty,” and a total of nine articles published in peer reviewed journals were located by the author. Of these nine articles; two are randomized controlled clinical studies,6 7 one is a case-controlled clinical study without randomization,8 one is a descriptive uncontrolled case study of sedation protocols,9 one is a descriptive controlled case series for dental equilibration,10 one is a case report,11 and three are review articles involving expert opinion and case series.12–14 Based on the grade of evidence15–17 (Table 1) with these nine articles: two are Grade I evidence,6 7 two are Grade III evidence,8 10 and the remaining five are Grade IV evidence.9, 11–14 It is interesting to note that the two Grade I evidence studies concluded that dental floating and improved rostral caudal mobility of the mandible did not affect weight gain, feed digestibility, fecal particle size, or body condition score.6 7 In summary, even though dental floating is a procedure that has been performed commonly in the horse for many decades, there is minimally published research with very low evidence of scientific effect for procedures involving odontoplasty in the equine patient.

### Table 1. Levels of Evidence. From the Center for Evidence Based Medicine Website. Available at: www.cebm.net.

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<th>Grade of Evidence</th>
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<td>Grade II Evidence</td>
<td>Randomized controlled clinical study in a laboratory setting</td>
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<td>Grade III Evidence</td>
<td>The following in peer-reviewed journals:</td>
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Bone Physiology, Metabolism, and Biomechanics

Bone is very dynamic in terms of physiology and biomechanics. Bone remodeling depends on the interaction between osteoblasts and osteoclasts. Osteoblasts can originate from preosteoblasts circulating in the blood, perivascular mesenchymal cells, and precursor cells within the periodontal ligament. Osteoclasts originate from a hematogenic line of large monocytes derived from stem cells in the bone marrow. The cellular activity of osteoblasts and osteoclasts is directly regulated by the interaction between receptor activator of nuclear factor kB ligand on osteoblasts, the receptor activator of nuclear factor on osteoclasts, and the decoy receptor osteoprotegerin.18, 19 Wolff’s Law4, 5 describes the net effect based on the dynamics of the cellular activity due to orthodontic forces. It is the principle that describes the response of biologic hard and soft tissues as they become distorted due to external forces. The forces will affect the form and function of bone, tooth, and surrounding soft tissue. These changes will lead to changes within the internal architecture of the hard and soft tissue.

During mastication, orthodontic forces are delivered to the maxilla and mandible. The load on the maxilla is primarily compression and the stress is distributed evenly throughout the entire cranium. With the expansive lattice network of the nasal turbinates and sinus structures, the stress is distributed through an architectural lattice so that the stress loads are minimized. As a result, the bone of the maxilla is a thinner trabecular (spongy) bone (Fig. 1). The load on the mandible is primarily a bending and torsion stress. Unlike the maxilla, the mandible must absorb the entire load from the mastication force. With adaptation to occlusal forces (Wolff’s Law of bone remodeling), the mandibular bone is much stiffer and stronger than the maxilla. The bone of the mandible is composed of thick cortices connected by relatively coarse trabeculae.20 Due to the anatomy and design, the mandible has four types of forces applied to the bone during mastication (Fig. 2). The first two forces are the tensile and compressive forces. The tensile force is primarily along the alveolar margin whereas the compressive force is along the ventral margin of the

### Table 2. Classifications of Occlusion

<table>
<thead>
<tr>
<th>Orthodontic classification</th>
<th>Orthodontic description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class O</td>
<td>Normal occlusion relative to the species and breed.</td>
</tr>
<tr>
<td>Class I</td>
<td>Neutroclusion where both the mandible and maxilla are normal length. Teeth are in a normal mesiodistal location. Teeth are displaced in a buccal, lingual or palatal orientation. Rotated or crowed teeth.</td>
</tr>
<tr>
<td>Class II</td>
<td>Distoclusion where either the mandible is short or the maxilla is long.</td>
</tr>
<tr>
<td>Class III</td>
<td>Mesiodistoclusion where either the mandible is long or the maxilla is short.</td>
</tr>
<tr>
<td>Class IV</td>
<td>Mesiodistoclusion is a special classification where one jaw is in mesiodistoclusion and the other is in distoclusion.</td>
</tr>
</tbody>
</table>
mandible. The other two forces are inward and outward torsional or twisting forces along the axis of the mandibular body. The masticatory muscles tend to roll the long axis of the mandible in by inverting the alveolar margin and evert ing the ventral margin. The bite force tends to rotate the long axis of the mandible in the opposite direction by rolling the mandible out so that the alveolar margin tends to evert and the ventral margin is inverted. When excessive torsional or twisting forces of the mandible occur, the periosteum will react and create additional support or bone exostosis in response to the surface strain. These areas of exostosis are called “Tori” (Fig. 3).

The temporomandibular joint (TMJ) is the principle adaptive center for determining the proper relationship in all three planes of space (transverse, occlusal, and anterior-posterior) for the maxilla and mandibles. When jaw structure and function is altered, the TMJ has the ability to adapt, relocate, and even regenerate so that functional mastication is maintained. In humans, following a unilateral subcondylar fracture and a medially displaced condyle head (due to forces from the superior pterygoid muscle), the displaced condyle head will resorb. A new condyle will form and replace the original condyle with full normal function and no significant deviation of the mandible. In domestic small animals (dogs and cats), it has been shown that if restriction to mobility of the TMJ occurs through ankylosis; 90% of the time it is “false ankylosis” due to extra-articular changes of the TMJ.

Orthodontic Forces

The equine orthodontic force applied during mastication has been measured at 248 newtons (55 lb/force) in the closing stroke and 875 newtons (196 lb/force) in the power stroke with the first cheek teeth (306/406). A force as high as 1925 newtons (432 lb/force) has been calculated for the power stroke with the last cheek teeth (311/411). Forces for physiological tooth movement typically only require 0.04–0.06 lb/cm² of pressure or less. The force should be less than capillary blood pressure so that bone necrosis does not occur. Pressure is the amount of force applied over a given surface area. By estimating the average surface area of the crown of an equine cheek tooth to be
approximately 6.25 cm², the calculated pressure values would be 8.8 lb/cm² for the closing stroke of the first cheek tooth, 31.36 lb/cm² for the power stroke of the first cheek tooth, and 69 lb/cm² for the power stroke of the last cheek tooth. Orthodontic pressures in the equine patient range between 25- and 197-fold above the required pressure for tooth movement. This extreme difference between orthodontic pressure and physiologic pressure demonstrates how a minor change with odontoplasty can have a tremendous influence on tooth movement.

There are six types of tooth movement that can occur. The types of movement are listed below from the easiest to the most difficult.

1. Extrusion is movement of the tooth out of the alveolus. It is best to use light forces to reduce the chance of accidental avulsion.
2. Tipping is the most common orthodontic movement, in which the crown is affected primarily. The true center of rotation is located at the junction of the middle and apical thirds of the tooth. The root/apical third of the reserve crown will slightly move in the opposite direction of the crown. Light continuous force is best for tipping movement.
3. Radicular (root) movement is referred to as root tipping, in which the fulcrum is between the coronal and middle third of the root. The coronal edge is held stationary while force is applied to the neck of the tooth.
4. Rotation refers to rotation around the long axis of the tooth. All periodontal ligament fibers are stretched in the same spiral direction. Recoil is a major problem. Light intermittently applied forces are best.
5. Translation is the bodily movement of the entire tooth by using an appliance that is fixed to the crown. Movement is best achieved with light forces initially followed by moderate forces.
6. Intrusion is movement of the tooth into the alveolus. Force is applied in the same direction as occlusal forces (the periodontal ligament is designed to resist this movement). It is best to use light forces to reduce the chance of apical resorption and pulp necrosis secondary to compression of apical vessels.

3. Results and Discussion: Class I Malocclusions

Skull Asymmetry

Skull asymmetry will predispose the equine patient to occlusal abnormalities. Typically, these are Class I malocclusions that involve the incisors, premolars, and molars, and may develop into Class IV malocclusions (Table 2). Skull asymmetry commonly involves the maxilla and incisive bone. As mastication occurs with an asymmetrical skull, the forces applied to the premolars and molars of the maxillae and mandible become disproportionate. As a result, tipping of these teeth may occur to allow for equal forces to be applied between the maxilla and mandible. As the cheek teeth shift/tip, the occlusal angles of the right and left arcades will change to accommodate functional mastication. As a result of the shift with the occlusal forces on the cheek teeth, the incisor teeth develop an offset asymmetrical wear pattern or incisor diagonal where there is excessive attrition of the mandibular incisors in the direction of the maxilla deviation. Maxillary incisors will have increased attrition opposite the direction of the maxilla deviation. Conversely, inadequate attrition occurs with the over long maxillary incisors that are in the same direction as the maxilla deviation.

The results of the study described skull asymmetry by noting a decrease in molar (and premolar) excursion on the side opposite the elongated maxillary incisor(s). Corrective odontoplasty procedures (not clearly described in the materials and methods) did not significantly improve the cheek teeth excursion along the opposite side of the maxillary incisor(s) elongation.

Corrective odontoplasty should focus on the premolars and molars so that the occlusion will allow for functional mastication. Excessive odontoplasty is not indicated. Care should be instituted to try to maintain the occlusal angles that the masticatory forces have created. Equalizing or balancing the occlusal angles will make it more difficult for the asymmetric patient to masticate. Once a functional occlusion has been established with the cheek teeth, the occlusion of the incisors can be evaluated. If the over-long incisors (inadequate attrition) compromise the occlusion of the cheek teeth, minimal odontoplasty may be indicated.

Maleruption

The equine incisors, premolars, and molars are considered to be radicular hypsodont teeth that continually erupt. As a consequence, a malerupting hypsodont tooth has the potential to create more dental pathology than a brachydont tooth. In the equine patient a continual maleruption may lead to periodontal and/or endodontic pathology. Maleruptions can be developmental or genetic.

Developmental maleruptions may occur when there is a change in masticatory forces due to missing or overlong teeth. Typically, the orthodontic movement with a developmental maleruption is tipping. Careful evaluation of the occlusion is indicated with the oral examination when determining the cause of a developmental maleruption. In addition, radiographic evaluation may be necessary to evaluate the periodontic and endodontic status of the tooth. Once the abnormal occlusal loads have
been identified and isolated, specific focal areas of odontoplasty should be applied to change or remove the forces on the tooth.

Genetic maleruptions may occur due to decrease in length of the maxilla/mandible or crowding from supernumerary teeth. A common orthodontic movement with genetic maleruption is rotation. These teeth should be evaluated radiographically and may need treatment other than odontoplasty (such as periodontal, endodontic, or extraction).27

**Tooth Elongation**

Tooth elongation refers to a tooth that is taller than the neighboring teeth in the same or contralateral arcade. When performing an oral examination, careful evaluation is indicated to discern whether the tooth is elongated or if there is excessive attrition with the adjoining teeth. An evaluation of the opposing tooth in occlusion should be performed.

Commonly, the tooth opposite the elongated tooth is where the pathology exists, whereas the elongated tooth is a normal tooth that has not been allowed to wear through normal masticatory forces of occlusion. As a result of a decrease in occlusal force with the elongated tooth, there may be less secondary dentin28,29 created above the pulp horns. With excessive odontoplasty this could create pulp exposure(s) and lead to pulpal inflammation and endodontic disease. Elongated teeth have an average depth of secondary occlusal dentin (SOD) of 10 mm. However, the range is between 2.5 and 17 mm of SOD. As a result of the wide range of SOD, if an elongated tooth is reduced to the occlusal level of the neighboring teeth, there is a 58% chance of pulp exposure occurring in the elongated tooth.28 The conclusion of Marshall et al was that tooth elongations should be treated “by a few millimeters at a time, over a prolonged period.” From an orthodontic force perspective, typically, only 1–3 mm of tooth removal is needed to change the forces of mastication and decrease the occlusal force directly over the opposing tooth (Fig. 4).

**Pathological Wave Pattern?**

In human orthodontics an example of a wave pattern does exist. Dental equilibrium would be when two opposing teeth are in occlusion, a balanced force existing so that the tooth height and alveolar margin are of similar height. If one of the opposing teeth in occlusion has excessive attrition or is missing, the opposite tooth will erupt into the space created. The alveolar margin bone30 (Margo alveolaris) of the missing tooth will resorb while new alveolar bone forms around the erupting tooth for support. With the remodeling of the alveolar margins, the orthodontic forces are once again in equilibrium.4 This scenario demonstrates that a wave pattern will coexist with dental equilibrium (Fig. 5). Equalizing or leveling the arcades is not necessary for dental equilibrium to occur.

In the equine patient, a wave pattern is a common finding that commonly involves the molars. The mandibular first and second molars tend to have a higher rate of attrition, whereas the maxillary first and second molars tend to be slightly elongated. In the author’s practice, a moderate wave is present approximately 42% of the time. The wave pattern may be explained by Wolff’s Law, as described previously. Supraeruption is a general term describing eruption of the crown beyond its occlusal plane. Supraeruption can be due to active eruption or periodontal growth. Periodontal growth is a type of segmental alveolar bone growth in which the peri-
odontal tissues (including alveolar bone and gingiva) develop in a coronal direction. If periodontal growth occurs; examination of the gingival margin relative to the occlusal surface should be evaluated prior to implementing corrective odontoplasty so as to prevent excessive crown reduction.

In normal horses it has been shown that the occlusal angles of the caudal mandibular molars tend to be steeper (≤30°) than the rostral mandibular premolars (19.2°). The angle tends to steepen with the arcade in a caudal direction. The maxillary premolars and molars tend to average the same angle of occlusion (range, 12.5–18°). Studies have suggested that the common condition of enamel points may be a normal condition. When evaluating a wave pattern, careful examination should be given to the vertical curvature of the caudal mandible along the alveolar margin and the height of the clinical crown relative to the gingival margin. A curvature of the arcade may be normal due to the curvature of the caudal alveolar margin of the mandible (curvature of spee or occlusal curve). Horses age 3–10 years have a significant difference in the height of the curve of spee compared with horses greater than 11 years of age. Masticatory force is significantly affected by the occlusal curve and the tooth location. Both a larger occlusal curve and teeth located more caudal result in increased masticatory force. If inappropriate or excessive crown reduction is performed on a caudal molar in a young horse, the functional mastication could be severely jeopardized.

The mandibular fourth premolar may have an appearance of being elongated due to attrition of the first and second mandibular molars. Careful and critical evaluation of the crown to gingiva height should be made to determine whether the crown height is truly elongated (Fig. 6). If the wave is severe and the fourth premolar is accurately diagnosed as elongated, then a slight (1–3 mm) and focal odontoplasty may be indicated. The removal of excessive tooth structure or drastic change in the occlusal angles could create excessive loss of occlusion and alter the normal masticatory forces.

Missing Dentition
Extractions, injuries, broken teeth, dental agenesis, etc. will lead to a missing tooth or teeth. Missing dentition may occur in the incisor arch and the cheek teeth arcade. Orthodontic forces are different when comparing the incisors to the cheek teeth.

The primary orthodontic force with missing dentition in the incisor arch is tipping. This tipping action may predispose the tipped incisor to abnormal premature wear along the distal or mesial aspect of the reserve crown, depending upon the direction of tipping. Minor odontoplasty of the opposing incisor(s) may be indicated to prevent abnormal attrition of the tipped incisors.

A sequence of orthodontic forces occurs with missing dentition in the middle of the cheek teeth arcade. Tipping is usually the first movement, followed by radicular movement. The final net effect of the orthodontic movement is translation. A cheek teeth arcade tends to act as a single large tooth with the mastication forces. Following the net translation movement, the cheek teeth arcade is shorter than the opposing arcade. The initial tipping movement will require light odontoplasty of the opposing tooth that would normally occlude with the missing tooth. As the arcade shortens with the net translation movement, frequent light odontoplasty
of the rostral and caudal teeth of the opposing arcade will be indicated.

Excessive Cingula, Enamel Point, and Transverse Ridge?
The maxillary cheek teeth have prominent vertical ridges (cingula or styles) along the buccal aspect. The mandibular cheek teeth also have ridges but they are not as prominent as in the maxillary cheek teeth. With the layering of the cementum, enamel, and dentin, these cingula give strength and support to the cheek teeth so that they are able to withstand the forces of mastication. Enamel points tend to develop along the occlusal extent of the styles (Fig. 5). Transverse ridges are linear cusps that run along the occlusal surface in a buccal to palatal/lingual direction (Fig. 6). The transverse ridges allow for an increased occlusal surface area for mastication. The combination of the enamel point, cingula, and transverse ridge allows for an enhanced tearing and shearing function with roughage/forage and an improved mastication process. Aggressive enamel point, cingula, and transverse ridge odontoplasty will weaken the dentition and reduce functional mastication (Fig. 7).

4. Conclusion
Masticatory pressures in the equine patient are 25–197-fold greater than orthodontic pressures required for tooth movement. Duration of pressure is even more important than the magnitude of pressure when dealing with equilibrating orthodontic forces and tooth movement. With the increased pressures and almost constant mastication of the equine patient, orthodontic forces are continually in effect compared with other species. As a result, minor changes with odontoplasty will still have a tremendous orthodontic effect, whereas excessive odontoplasty could be devastating. An orthodontic examination should entail an accurate evaluation of how masticatory forces are effecting a Class I malocclusion. Occlusal forces can be reduced or eliminated with minimal focal odontoplasty of the involved teeth. A diagnosis should be made on a “tooth-by-tooth” basis so that a treatment plan of precise focal odontoplasty can be developed and implemented.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

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How to Improve the Diagnostic Quality of Your Dental Radiographs

Robert M. Baratt, DVM, DAVDC/Eq

1. Introduction
Many practitioners struggle to obtain radiographs of the horse’s teeth that are of diagnostic quality. The most common factors responsible for poor quality dental radiographs are below:

- Patient movement
- Improper positioning of “standard” views
- Poor radiographic technique (combination of kVp and mAs)
- Outdated or malfunctioning radiographic equipment or imaging software

2. Materials and Methods
Obtaining diagnostic dental radiographs of the horse requires adequate sedation. This often means sedation more profound than is required for oral examination or performing minor dental procedures, such as floating sharp enamel points on cheek teeth. As an example that many practitioners are familiar with, this would be similar to the level of alpha-2 adrenergic sedative analgesic used prior to ketamine anesthetic induction. With this level of sedation, the horse will be unresponsive to placement of the radiographic sensor next to the head and will rest the chin on a low support, such as a step stool. If using a direct radiography (DR) system, resting the sensor on the same stool will usually eliminate motion artifact (Fig. 1). If using computed radiography (CR) systems, the cassette can be secured to the head with elastic straps (bungie cords); with this arrangement, even if the horse’s head moves there will not be blurring of the image. For the intraoral views of the incisors and canine teeth, it will often help to combine the alpha-adrenergic sedative analgesic with butorphanol tartrate (4.4–8.8 ug/kg, IV).

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It is very helpful to strive for standard views of the horse’s teeth. This greatly improves the diagnostic quality of the images and permits more productive consultation with radiologists and equine veterinary dental specialists. Be as fussy with your dental radiographs as you are with your pre-purchase radiographs of the extremities. One of the great advantages of digital radiography is the ability to take additional views when the image is unsatisfactory. With practice, the number of “retakes” will become fewer. Some positioning tips that may be helpful are below:

- Obtain the intraoral views first, when sedation is most profound. This will improve your chances of the horse not chewing when the imaging plate/sensor is placed within the mouth (Fig. 2).
Proceed to the DV views next. With the horse's head in a low position, with the chin resting on a stool, it is possible to hold the generator and look directly over it to line up the central beam perpendicular to the dorsal plane, which is parallel to the plane of the hard palate (Fig. 3). There are multiple methods of obtaining right and left offset-mandible DV views (Fig. 4), and these are likewise best to obtain during this initial period of more profound sedation. Survey DV views of the cheek teeth should be obtained with the central beam perpendicular to the long axis of the head (the dorsal plane, which is parallel to the hard palate). However, given that the rostral and caudal cheek teeth are not at a 90°
Fig. 3. Positioning for the DV view. Line up the central beam perpendicular to the dorsal plane (which is nearly parallel to the palate and the sensor) by looking directly over the x-ray generator.

Fig. 4. Positioning for the DV with offset mandibles. One assistant is using gauze bandage material to pull the maxilla to the horse’s left, whereas the other pulls the mandibles to the right. A commercially available device (right) designed to offset the mandibles.

Fig. 5. Straight DV view (left) and the DV with the mandibles offset to the horse’s left (right). Note that the central beam is aligned down the long axis of the right maxillary 3rd premolar (107) in the image on the left, with poor detail of the maxillary molars. In the image on the right, the central beam is directly down the long axis of the right maxillary 3rd and 4th cheek teeth (108, 109), with poor detail of the 2nd premolar (106) and the 3rd molar (111).
angle to this plane, their images will be slightly blurred (Fig. 5). Slight rostro-caudal or caudo-rostral adjustment of the central beam will be necessary to obtain a good long-axis image of these teeth.

- The straight lateral (laterolateral) view is obtained with the central beam centered on the occlusal aspect of the cheek teeth, at the level of the rostral end of the facial crest. The right-left marker should indicate the side of the head that is closest to the imaging plate/sensor. The technique should be chosen that gives good detail of the paradental alveolar bone and sinus anatomy (Fig. 6).

- The oblique lateral views should be obtained with the mouth held wide open with a bite block or dental speculum. Using the American College of Veterinary Radiology labeling convention, these views are the Lt30D-RtVO, Rt30D-LtVO, Lt45V-RtDO, and Rt45V-LtDO views. It is important to have the mouth wide open.

Fig. 6. The right lateral view. The sensor is on the right side of the horse’s head, so the right (R) marker is used to identify the directionality. The technique used maximizes the detail of the sinus anatomy.

Fig. 7. Lt30V-RtDO extraoral view of the canine teeth. The right maxillary canine tooth is projected ventral to the left maxillary canine tooth.

Fig. 8. Lt30D-RtVO open-mouth view. The apices of the right maxillary cheek teeth are isolated in this view. This view also isolates the crowns of the right mandibular cheek teeth.
As with the straight lateral, with these orthogonal views the central beam is directed perpendicular to the long axis of the head. When the long axis of the head is parallel or perpendicular to the ground, it is easy to align the central beam. However, the head is usually at an angle to the vertical or horizontal, so care must be taken to keep the central beam perpendicular to the long axis of the head for these lateral oblique views. For example, it is easy to obtain caudorostral obliquity when positioning for the ventrodorsal (VD) lateral oblique view of the mandibular cheek teeth. Although the mandibular canine teeth are usually imaged with the intraoral views of the mandibular incisors, the maxillary canine teeth apices are often too caudal for imaging using the intraoral technique. In this case, use Rt30V-LtDO and Lt30V-RrDO extraoral views with the central beam 5–10° caudal to the frontal plane (e.g., the central beam is angled slightly in a caudal-to-rostral direction). This will project the maxillary canine tooth near the plate/sensor ventral and caudal to the contralateral maxillary canine, which is closer to the generator (Fig. 7).

3. Discussion

The Lt30D-RtVO view will isolate the apices of the right maxillary cheek teeth; with the mouth wide open, this view will also isolate the coronal aspect of the right mandibular cheek teeth (Fig. 8). The Rt45V-LtDO radiograph, if carefully positioned, will isolate the apices of the left maxillary cheek teeth in the space between the mandibular cheek teeth and the crowns of the right maxillary cheek teeth. If the plate/sensor is large enough, this positioning will also image the apices and reserve crowns of the left mandibular cheek teeth (Fig. 9). This open-mouth VD lateral oblique view will usually project the palatal roots of the maxillary cheek teeth, whereas the DV lateral oblique view projects the buccal roots of the maxillary cheek teeth. These two views are complementary and should be considered together in the evaluation of the apices and reserve crowns of the maxillary cheek teeth.
As a starting point, use the technique for 3rd phalanx imaging for the intraoral views of the incisors, the fetlock technique for the lateral extraoral views, and the stifle technique for the DV views of the skull. For the Cuatro Slate DR system used in this publication, the generator was 20mA, the focal-film (sensor) distance was 26 inches, and the kvp/mAs used is below:

- Incisors (and canine teeth): 60 kVp/1.6 mAs
- Cheek teeth, lateral views: 75 kVp, 2.5 mAs
- Caudal mandibular cheek teeth, lateral views may require 80 kVp/3.2 mAs
- DV views: 90–100 kVp/3.6–4.5 mAs

Note that the straight lateral view will often have underexposure of the cheek teeth to obtain the correct exposure of the sinus anatomy. Commonly, the manufacturer’s suggested technique for skull radiographs results in burn-out (overexposure) of the bony anatomy of the paranasal sinuses. Reducing the kvp by 10% will likely remedy this. The mandibular 3rd molars are also often challenging to image, primarily due to the thickness of the overlying masseter muscle. The clinician can try using the maximum kvp setting and doubling the mAs. Alternatively, the mandibular 3rd molar can be imaged with an open-mouth DV and slightly caudal-rostral projection (Figs. 10 and 11). Some systems, notably the portable equine CR systems, may not have software algorithms that provide ideal imaging of the cheek teeth and sinuses. If changing the technique as described above does not improve your image, then it is likely that the algorithms require adjustment by the technical support service provided by that particular software company. If the radiology system cannot image the stifle, then it will similarly be unable to image the mandibular molars.

If the imaging software seems to be preventing proper contrast and detail of the area of interest, it may prove helpful to collimate the generator so that a smaller portion of the imaging plate/sensor is exposed, and the center of the plate/sensor is then centered on the area of interest (e.g. the caudal mandible, or maxillary sinuses).

With some practice, the clinician should be able to obtain diagnostic quality radiographs with most of the portable radiographic systems currently in use.

4. Summary

Although the equine head has a complex anatomy, the teeth and sinus anatomy can be imaged quite well with portable digital radiographic systems that most equine practitioners have in clinical practice. The prerequisites for obtaining diagnostic images of the equine dentition are adequate sedation, proper positioning, and technique. Recognition of the “standard views” in an equine dental imaging study will assist the clinician in obtaining images that are of diagnostic quality for immediate use in the field, or for consultation. Clinicians are encouraged to obtain both right and left lateral oblique views for comparative purposes. The oblique lateral views are most informative if they are obtained with the mouth wide open.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

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Reference

Caps, Canines, and Wolf Teeth in the Horse:  The Quick Guide to Embryology, Eruption, Exfoliation, Extraction, Reduction, and Other Things You Need to Know

Lynn A. Caldwell, DVM

1. Introduction
The primary dentition of the horse, also known as the deciduous dentition, is frequently encountered by the equine practitioner either during routine procedures or as a primary complaint, and is a never-ending source of discussion. Questions regarding the first premolars, also known as “wolf teeth,” will still elicit strong opinions regarding their extraction. In the past decade, little has changed about the way we approach the canines, but our knowledge of the unique nature of radicular hypsodont dentition in the horse, however, has evolved significantly.

2. The Deciduous Dentition
The Modified Triadan system designates the deciduous, or primary dentition, as the 500 through 800 teeth, with the 500 arcade indicating the upper right quadrant, 600 is upper left, 700 is lower left, and 800 is lower right. The central incisors are tooth number 001 and the fourth premolars are Triadan tooth number eight. The eruption schedule is depicted using the Modified Triadan System in Table 1.

The deciduous incisors are small and round with an obvious “neck” at the intersection of the crown and root at the gingival margin. Deciduous incisors are very white and shiny because there is no cementum on their labial surface, leaving the pe-
ripheral enamel exposed. The occlusal surface is ovoid and becomes “level” or “in wear” approximately 6 months after eruption and has exposed secondary dentin inside the outer ring of enamel. An enamel infundibulum containing cementum is visible on the occlusal surface of the deciduous incisors, similar to the permanent incisors. The deciduous radicular hypsodont crowns undergo wear or “suffer attrition” while the permanent teeth are developing within the bone.

Permanent (secondary or succedaneous) teeth develop in a dental follicle or sac just underneath the root of the primary tooth. The permanent incisors develop lingually/palatally to the deciduous incisors. The permanent premolars develop almost directly underneath the deciduous premolars. The molars are permanent teeth without deciduous precursors. The dental follicle contains the enamel organ and primitive dentin and pulp. Within the dental follicle of the incisors and maxillary premolars, a blood vessel enters the developing permanent tooth from its crown to form the infundibula. Infection or loss of the primary tooth may damage the developing secondary tooth because of the intimate proximity of the two structures. For this reason, it is important to know the exfoliation schedule of the deciduous teeth and the eruption schedule of the permanent dentition.

As the developing permanent tooth moves through the “eruption tunnel” underneath the deciduous tooth, pressure develops upon the root of the primary precursor. This pressure, among other factors, causes the deciduous tooth to undergo root resorption and to move further orally. As the deciduous tooth root resors and suffers simultaneous attrition of its crown, the permanent tooth continues to move orally and cause resorption of the bone. As the succedaneous tooth reaches the level of the gingiva, the dental follicle and oral epithelium fuse to form the gingival attachments. The deciduous incisor becomes a loose, rootless structure or “cap” labial to the erupting permanent incisor. The deciduous premolar also becomes a thin “cap” just prior to exfoliation.

Eruption and exfoliation tends to occur in pairs. The mandibular caps tend to exfoliate shortly before the maxillary caps exfoliate, although this is highly variable. Masticatory forces, abrasive forces of feed material, or movement of the lips and tongue aid in the shedding of the caps. Exfoliation should result in both members of an analogous pair being shed at approximately the same time. If this is not the case, the cap is considered to be “retained” or “persistent.” The exfoliation schedule for horses is as follows in Table 2.

The decision to extract a cap is centered around the exfoliation schedule and the clinical condition of the tooth. The succedaneous (permanent) tooth should be visible above the gingiva and the cap should be mobile when touched with fingers or forceps (Fig. 1).

Premature removal of deciduous teeth can be an invasive surgical procedure and may damage the underlying developing secondary tooth. Rupture of the immature dental follicle of the permanent tooth will stop development of the enamel, prevent proper formation of the gingival attachment, and may result in loss of that tooth completely.

Extraction of persistent deciduous teeth is generally neither difficult nor painful for the horse. The exception would be if the tooth is broken or retained with incomplete resorption of the root. A deciduous tooth is considered retained or persistent when its counterpart in the adjacent arcade has already successfully exfoliated (Fig. 2, A and B).

The deciduous incisors, when retained, tend to have long roots that have been resorbed lingually or

<table>
<thead>
<tr>
<th>Primary (Deciduous Tooth)</th>
<th>Approximate Eruption Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>501/601/701/801 (central incisors)</td>
<td>Age 0–8 d</td>
</tr>
<tr>
<td>502/602/702/802 (lateral incisors)</td>
<td>Age 4–6 wk</td>
</tr>
<tr>
<td>503/603/703/803 (corner incisors)</td>
<td>Age 6–9 mo</td>
</tr>
<tr>
<td>506/606/706/806, 507/607/707/807, 508/608/708/808 (2nd, 3rd, 4th premolars)</td>
<td>Age 0–14 d</td>
</tr>
</tbody>
</table>

| Table 2. Exfoliation Schedule of Deciduous Dentition in the Horse (Modified Triadan) |
|---------------------------------|------------------|
| 501/601/701/801 | Age 2 1/2 y |
| 502/602/702/802 | Age 3 1/2 y |
| 503/603/703/803 | Age 4 1/2 y |
| 506/606/706/806 | Age 2 y 8 mo |
| 507/607/707/807 | Age 2 y 10 mo |
| 508/608/708/808 | Age 3 y 8 mo |

Fig. 1. Deciduous cap 607 ready to exfoliate. Green arrow points to the succedaneous tooth 207 erupted and above the gingival margin while purple lines surround and point to the cap.
palatally but not labially. Extraction will require anesthesia of the gingival attachments to avoid causing discomfort upon incision and elevation of the gingiva from the retained tooth. If a persistent deciduous incisor is left in place for too long, the permanent incisor may be forced lingually or palatally. After the persistent deciduous incisor is removed, the permanent tooth will move into line with the rest of the incisors fairly quickly. The premolars, when retained, tend to have root spicules palatally, or are fractured and only a piece is retained, which can then retard the post-eruptive phase of the permanent tooth and may lead to formation of malocclusions.

Prior to extraction of any cap, it is necessary to elevate the gingival attachments, if any. By judiciously cutting any remaining attachment to the gingiva, avulsion of gingiva or mucosa can be avoided and loss of blood kept to a minimum. Cutting the gingival attachment can be facilitated by the use of viscous lidocaine gel\textsuperscript{a} or subgingival infiltration of lidocaine\textsuperscript{b} or mepivacaine\textsuperscript{c} with or without epinephrine. A small periosteal elevator\textsuperscript{4} is useful to cut the attachment of any junctional epithelium that remains on a deciduous incisor. A pair of left and right Cryer elevators\textsuperscript{5} works well to cut the junctional epithelium of the deciduous premolars. Luxation (sharp cutting of the periodontal attachment) should not be necessary in the case of most deciduous caps that are ready to be removed (Figs. 3 and 4).

When all gingival attachments have been cut, forceps may be applied to remove the tooth from the mouth. The persistent deciduous incisors should just lift out. Premolar caps should be rotated axially and then checked for root spicule fragments in the gingiva of the palate. Root fragments left in the palate can be a source of irritation or periodontal disease. Mild periodontal disease is a frequent finding with normal deciduous caps that have become so thin and loose as to allow feed material to become entrapped underneath the cap.

Development of the secondary dentition in the horse may cause visible eruption cysts of the head and are normal in three and four year olds. The boney swellings should be symmetrical and non-painful. These eruption cysts are commonly visible on the ventral border of the mandible and correspond to the development of the third and fourth premolars (Fig. 5 and 6).

Not infrequently, the development of the maxillary fourth premolars will result in a swollen and boxy appearance to the face, especially in miniature horses. These swellings should resolve within a few weeks after the deciduous tooth has shed and the permanent tooth has reached its position within the arcade. Asymmetrical swelling of the eruption cysts with associated inflammation and pain may suggest a problem with eruption and exfoliation.

A commonly encountered problem with eruption and exfoliation in horses occurs with the fourth pre-
molars. The reason for this is that the fourth premolar (No. 08 tooth) is the last deciduous cheek tooth to erupt and shed. This tooth must form an eruption tunnel between the first molar (No. 09 tooth), which erupts into the mouth at 1 year of age, and the third premolar (No. 07 tooth), which erupts approximately 1 year before the fourth premolar (No. 08). The fourth premolar must form an eruption tunnel in the middle of an arcade of teeth held tightly together by the interdental ligament and the angulation of the first and last cheek teeth. The interdental or transseptal ligament is the structure that runs along the alveolar process and connects the crowns of the teeth together to form the tight interproximal relationships that prevent food from becoming entrapped between the teeth.6 This tight space afforded to the fourth premolar leads to the aforementioned eruption and exfoliation problems.

Impaction of the fourth premolars will cause painful, inflamed, and potentially infected dental follicles. Inflamed maxillary eruption cysts may interfere with the normal function of the nasolacrimal duct, resulting in the development of persistent ocular discharge. Inflamed mandibular eruption cysts may form a fistulous tract through the mandible and discharge either subcutaneously or cutaneously. The veterinarian should understand why it is not wise to remove the deciduous fourth premolar cap in this situation. By removing the cap, the interdental ligament pulls the adjacent teeth together even tighter, exacerbating the pinching effect and encouraging impaction of the erupting tooth. Therefore, it is recommended to leave the No. 08 cap in place as long as possible until the permanent fourth premolar has moved well above the alveolar process and into the correct position in the arcade.

The permanent fourth premolar (No. 08) will frequently erupt either palatally, lingually, or buccally when the eruption tunnel does not afford enough room for completion of eruption. The developing tooth may also rotate along its vertical axis to accomplish eruption. The premolars are longer mesial to distal than they are wide, so the unerupted permanent tooth may rotate 90 degrees, usually such that the buccal side occupies the mesial position. This will result in periodontal disease later on because the enamel columns in the interproximal space trap feed material. It may not be possible to prevent rotation of the tooth, or lingual, palatal, or buccal displacement, but these maleruptions are preferable to impaction. Radiographs are necessary for complete evaluation in the case of eruption and exfoliation problems.

Removal of deciduous caps is most appropriate if they are ready to shed during routine dental procedures or if there is a clinical problem that is discovered during a complete oral and dental health examination. Poorly timed exfoliation while being ridden has reportedly caused violent, explosive episodes in surprised young horses, so a comprehensive oral health assessment is indicated for all horses prior to the commencement of training in the bridle, and frequently during the eruptive and exfoliative years (up to 5–6 years of age). Caps should only be removed when they are ready to exfoliate or if there is no other option because their presence may endanger the developing permanent tooth. The fourth premolar caps should be left in situ for as long as possible, especially in the case of partial or complete impaction.

Judicious odontoplasty of the deciduous teeth can be performed to remove sharp enamel points, but odontoplasty of the deciduous incisors is rarely necessary. Doing so, especially during the eruptive and exfoliative phase of the young horse, can place too much occlusal pressure upon the newly erupted permanent teeth if the deciduous incisors are brought down to level the arcade. The newly erupted incisors are not strong enough to withstand occlusal forces. The adjacent deciduous incisors will continue to function in occlusion while the erupting incisors are reaching the occlusal level of the arcade and developing additional strength by adding secondary dentin to the structure of the tooth.
The extraction procedure should always be performed with local anesthesia and with care as to the proximity of the palatine artery. Local anesthesia is accomplished by infusing mepivacaine, with or without epinephrine, just underneath the mucosa palatally and buccally to the tooth. The palatine artery lies just palatal to the maxillary cheek teeth and can easily be lacerated by dental instruments, resulting in an impressive loss of blood. Many luxators (instruments that sharply cut tissue) and elevators (instruments that tear tissue with a torqueing motion) are available for wolf tooth removal. An assortment of luxators that can accommodate various sized wolf teeth is recommended, along with an orthopedic mallet. The use of the orthopedic mallet provides a controlled force for cutting any periodontal attachments, greatly reducing the risk of slippage into the mucosa of the palate or laceration of the palatine artery. It is the author’s preference to avoid the Burgess-type extraction instruments, given that they tend to core out the tooth and surrounding gingiva, causing excessive bleeding, and one can easily break the tooth off in the lumen of the Burgess instrument. With time and experience, each individual operator will find the instruments that work best in their hands.

4. The Canine Teeth

The canine teeth are No. 04 in the Modified Triadan system. Horses have zero to four canines, with four permanent canines being the usual number in the male horse. Deciduous canines may precede the permanent canines and resorb during eruption of the permanent canine. The permanent canine erupts between 4 and 6 years of age and reaches its full length of 5–7 cm a few years later. Sharp and spade shaped with a convex bump on the lingual/palatal surface, the canine teeth are specialized in male equidae for fighting. Females typically do not have permanent canine teeth, but may have persistent unerupted deciduous or only barely erupted permanent canines that remain throughout their lives. It has been frequently spoken and written in the recent past that the canine teeth “are the only brachydont teeth in the horse.” This statement is not consistent with the facts. Horses have radicular hypsodont dentition and are not a brachydont species. All the teeth in the horse are of the radicular hypsodont type and behave as such, including the canines. Although the canine teeth are completely enveloped in enamel with a smattering of external cementum, there is no cemento-enamel junction of the crown and root in the equine canine tooth. This is typical of radicular hypsodont dentition.

The canines in a Class 1 occlusion (neutro-occlusion or normal occlusion) do not occlude. They are located in the interdental space between the third incisor and the first or second premolar. This space is also known as “the bars” of the mouth. The mandibular pair of canines is mesially situated to the maxillary pair as in dogs, cats, and humans, and extend deeply into the bone of the mandible leaving only 10–20% of the crown visible above the gingiva (Fig. 8, A and B). The canine teeth have a single pulp chamber that is very large when newly erupted. The pulp chamber can be as close as 5 mm from the tip of the crown, especially in young animals with less internal secondary dentin. The apex is not fully formed for several years after eruption, also typical of a radicular hypsodont tooth. Extraction of the canine teeth requires a surgical procedure because of the necessity of removal of alveolar bone, especially in the mandible.

Radiographic evaluation of the canine teeth utilizes intra- and extra-oral techniques. Direct radiographic evaluation of the canine teeth with the horse in a standing horizontal position shows the apices of the premolars, with the cusps of the first premolar and canine superimposed. When standing vertically, the eruption position of the canine is well above that of the premolars, which is more consistent with the facts. Horses have zero to four canines, with four permanent canines being the usual number in the male horse.
ography plates generally cannot be inserted into the mouth far enough to image the maxillary canines, but are able to image the mandibular canines (Fig. 9, A and B). An extra-oral ventral to dorsal oblique view will produce diagnostic images of the maxillary canines without overlap (Fig. 8, A and B).

Judicious crown reduction of the canine teeth is typically performed in horses to “disarm” them, prevent tongue and dental trauma while bridled, prevent human injury when working in and around the horse, and prevent crown fracture in stalled horses or in horses that have a Class 2 or disto-occlusion wherein the canines may interfere with one another. The nature of the radicular hypsodont dentition allows some careful crown reduction of the canines but caution and planning with respect to the age of the horse must be exercised to avoid causing permanent damage to the tooth. Direct pulp exposure or indirect pulp exposure (live dentin containing live odontoblastic processes usually within a few millimeters of the pulp proper) will result in a degree of pulpitis. In response to the pulpitis, the tooth will undergo a process of repair or death, and may result in an “endo-perio” lesion whereby the tooth creates a lateral canal for drainage into the periodontium. Depending upon the age of the horse, depth of the pulp horn and degree of exposure and inflammation, the tooth crown may become compromised and brittle.

Careful reduction of the crown of the canine tooth in this radicular hypsodont species is possible and beneficial in some situations but overzealous reduction of the canines is not recommended as pulp exposure may occur, particularly in younger horses. In the young horse, when pulp exposure is of the highest concern, the canine may be simply blunted to remove the sharp cutting edges of the spade-

Fig. 8. A and B, Direct radiography image showing both the amount of crown above the alveolar bone using the ventral to dorsal oblique technique for imaging the maxillary canines. Green arrow indicates angle for extra-oral imaging of maxillary canines.

Fig. 9. A and B, Intra-oral images of the incisive regions are not able to include maxillary canines. An extra-oral ventral-to-dorsal oblique technique is needed (see Fig. 8A maxillary on left.) Intra-oral images of mandibular incisors are able to image the entire mandibular canines (see Fig. 8B on right.).
shaped, newly erupted teeth. In the female horse, the deciduous canines, if present, may be extracted to provide a more comfortable interdental space for the bit. In contrast with the analogous teeth in a dog, crown reduction is not possible in a brachydont tooth without the use of an immediate restorative procedure to seal off and protect live odontoblast processes within exposed secondary dentin.

It has also been previously thought that crown reduction of the canines leads to increased calculus deposition on the canines. This has not been the author’s experience, although periodontal disease with concomitant bacterial flora change anywhere within the horse’s mouth may contribute to this condition. Calculus should always be removed during any routine dental procedure, and by doing so, the crowns of the canines may be clearly evaluated. Calculus on the canine teeth may cover up a pulp granuloma or other evidence of endodontic or periodontal disease such as equine odontoclastic tooth resorption and hypercementosis, which may manifest itself in the canines before moving mesially into the incisors.9

Although the canine teeth are not occlusal teeth, they should always be examined and evaluated with every dental examination and treatment. Careful crown reduction may be performed to reduce usefulness of the canine teeth as weapons, to decrease interference with the bit and prevent damage to the tooth by the horse. Occasionally, extraction of a canine tooth is necessary, but this can be a major oral surgery.

Take-home points from each section include:

- Know the eruption and exfoliation schedule of the horse
- Do not remove excessive tooth structure from the deciduous dentition especially in the case of the incisors
- Unless necessary, do not remove deciduous dentition before the teeth are ready to shed and permanent dentition is visible especially in the case of the fourth premolars
- Wolf teeth may require removal or may be left in place per the owner and their veterinarian and they are best extracted with an assortment of luxators and an orthopedic mallet
- Canine teeth should always be evaluated with any comprehensive oral health assessment and treatment
- The canine teeth, especially the mandibular teeth, require experience and surgical skill to remove

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

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References and Footnotes


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Mentorship for Early/Mid-Career Success

Elizabeth M. Charles, DVM, MA

Formal mentorship programs improve employee satisfaction, retention and recruitment\(^1\) and are not only a critical tool for the equine practice owner, but for the equine associate veterinarian as well. Understanding the role of the mentor, the role of the mentee, and the critical skill sets necessary to form an effective mentor-mentee relationship ensures a successful outcome. Author’s address: 29083 Bent Tree Drive, Murrieta, CA, 92563; e-mail: betsycharles@mac.com. © 2016 AAEP.

1. Introduction

The idea of “mentoring” has been around for over 1000 years and the first use of the concept dates back to its use in Greek mythology in *The Odyssey* by Homer. However, the word “mentor” did not appear in the English language until after 1750 at which time it began to represent a sort-of father figure who took someone under his wing to shepherd professionally, often for long periods of time. The mentor was the authority figure and chose the person/people he would mentor.\(^2\) Its modern definition is somewhat vague but is usually a senior worker who provides guidance and mentorship to the younger employee so that the younger employee can learn and grow in his or her position within the organization. In the beginning, these programs were not formalized, nor were outcomes measured and their success or failure was largely due to the more experienced employee’s skill as a mentor. In the current equine veterinary job market, new graduates, especially those in the Millennial Generation, are increasingly choosing practices that have a formal mentorship program and are directing what those programs will look like. In fact, young workers say they value mentorship, coaching, and training more than they value money.\(^3\) Because the Millennial Generation makes up the majority of new graduates and those early in their career, it is imperative that seasoned practitioners pay attention to their needs and understand the characteristics that lead to a successful mentorship experience. If those in equine practice are going to recruit and retain the next generation of practitioners, a mentorship program strategy is critical.

In the last 10–15 years, organizations have begun evaluating mentorship programs to determine whether the programs are successful and some research has been done to better identify the characteristics necessary to be an effective mentor or mentee, while also elucidating the characteristics that make a mentorship program successful. Although this research is limited and much more work in this area is needed, a study done in 2013, by Straus et al\(^4\) looked at mentor–mentee relationships and provided an excellent overview of specific characteristics that lead to positive outcomes. This paper will explore their findings and provide a practical framework for both mentors and mentees to consider when evaluating and/or setting up a formal mentorship program in equine practice. Specifically, this paper will weave together the characteristics of a successful mentoring relationship...
with both the characteristics of effective mentors and the characteristic of effective mentees with an emphasis on what early and mid-career equine practitioners can do to make sure they know how to evaluate a program while also better understanding their role as either a mentee or a mentor.

2. Characteristics of Successful Mentoring Relationships
When considering entering into a mentor relationship, it is important for both the mentor and mentee to understand what characteristics can help provide a framework for success. It is also helpful to know what things can lead to failed mentoring relationships. Straus et al.4 identified five characteristics of an effective mentoring relationship. These include:

1. Reciprocity: bidirectional nature of mentoring, including consideration of strategies to make the relationship sustainable and mutually rewarding.
2. Mutual respect: respect for the mentor and mentee's time, effort, and qualifications.
3. Clear expectations: expectations of the relationship are outlined at the onset and revisited over time; both mentor and mentee are held accountable to these expectations.
4. Personal connection: human connection between the mentor and mentee.
5. Shared values: around the mentor and mentee's approach to research, clinical work, and personal life.

They also identified characteristics and consequences of failed mentoring relationships that can serve as warnings to mentees and a list of things to avoid for mentors. These include poor communication, lack of commitment, personality differences, perceived competition (or real), conflicts of interest, and a mentor's lack of experience.4

Equine practitioners, whether in academia, private practice, industry, or other venues within equine veterinary medicine, are incredibly busy. This is also true whether one is new in their career or more seasoned. Thus, taking on a mentor/mentee role can be seen as just another thing to add to the list without much thought on how to enter into such a relationship or what parameters will help ensure a successful outcome for both the mentor and the mentee. Making sure that both the mentor and mentee understand the pros and cons of mentoring relationships will take time on the front end, but understanding these ideas by taking the time necessary leads to much more likelihood of success.

3. Characteristics of Effective Mentees
Because the Millenial Generation is driving the development of formal mentorship programs in veterinary medicine, some of the responsibility of what the program looks like should come from the mentee. Straus et al.4 identified several characteristics of effective mentees which include the following:

1. Mentees should be open to feedback and be active listeners.
2. Mentees should be responsible, paying attention to time lines and taking responsibility for “driving the relationship.”
3. Mentees should show respect for their mentor by respecting meeting times, being prepared for meetings, attending meetings with topics for discussion, recognizing the mentor may have competing demands (i.e. meeting with other mentees, their own deadlines).

This quote, taken from a participant in Straus’ study exemplifies the expectations of today’s mentee.

“You can’t just go in and be an undifferentiated blob about what you want, you have to really have thought before you go in and meet with your mentor about what the issue is that you need help with and you know it’s much more useful if you bring your own analysis in with you and then the mentor can give you their analysis and you can talk.”4

Thus, new grads and early career equine practitioners play a huge role in developing meaningful mentoring relationships and fine tuning these skills during veterinary school is a must.

4. Characteristics of Effective Mentors
Although the responsibility of the mentoring relationship is shifting and changing as the Millenial Generation enters the workforce, the mentor still plays a large role in the mentoring relationship and Straus’ study provides several ideas about what types of characteristics lead to being an effective mentor which are listed below.

1. Mentors should be altruistic.
2. Mentors should be honest, trustworthy, and active listeners.
3. Effective mentors have substantial mentorship experience.
4. Effective mentors have professional experience (including networks or colleagues and collaborators) that can facilitate mentee development.
5. Effective mentors exhibit important relational characteristics, including being accessible and able to identify and support the development of potential strengths and skills in their mentees.4

Further, the Coalition of Counseling Centers, Inc. (CCC)/Mentoring Group suggests that mentors consider the following before entering into a mentoring relationship.

1. Have a good rationale for being (or not being) a mentor.
2. When asked to mentor, don’t say “yes” or “no” too quickly.
3. Recognize all you have to offer.
4. Negotiate several factors (including the structure of the relationship, how long will the relationship last, how often and where will you meet, what will the mentee work on in terms of goals and development activities, how will the mentor and mentee give each other feedback, how will you handle disagreements, what is confidential, and how much you will share with others).
5. Help your mentees lead the process.
6. Provide encouragement frequently.
7. Be ready to transition when it is time.2

With the gender shift that is happening in equine veterinary medicine, understanding the changing role of the mentor (away from father figure toward a more collaborative mutual relationship) is critical. The characteristics listed above combined with a shared development of the relationship between mentor and mentee is more likely to result in a positive mentoring relationship, one that is not only beneficial to the mentee, but is also beneficial for the mentor.

5. Conclusion
In closing, the mentor–mentee relationship is one that requires attention to the characteristics that lead to success. Fortunately, the work by Straus et al4 gives equine practitioners a framework to better understand these characteristics and look for them when considering entering a mentoring relationship. The final thing to consider is all the ways a mentor can help a mentee. If the mentee knows what they are looking for and the mentor is aware of whether he or she can provide it, the chance for win-win is increased. Again, Straus et al4 provide a list of three types of actions that mentors can take to help the mentoring relationship in a positive manner. These include 1) providing career guidance (includes advising, advocacy, networking, creating opportunities, goal setting, career monitoring, helping mentees navigate institutions/organizations, providing feedback, acting as a sounding board), 2) offering emotional support (sharing their own feelings honestly and encouraging their mentees to do the same, helping to identify possible stressors, check in to see how mentee is doing), and 3) helping the mentee focus on work/life balance.4

By taking an evidence-based approach to the mentoring relationship, equine practitioners, both young and old, mentor and mentee, can more effectively ensure that high quality equine veterinary medicine is passed on from one generation to the next.

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Declaration of Ethics
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The Author declares no conflicts of interest.

References
The Value of Mentorship for Practice Success

Michael F. Martin, DVM

Mentors can be very valuable resources for veterinarians. Even the seasoned practitioner can benefit in many ways by having a mentor. Author’s address: Retama Equine Hospital, Inc., 17555 Old Evans Road, Selma, TX 78154; e-mail: martindvm@retamaequinehospital.com. © 2016 AAEP.

1. Introduction

As veterinarians we are trained to treat horses and make them well. But how do we make our business well? Throughout my career I have seen great veterinarians falter because they were not good business people. Although I received a great veterinary education it did not prepare me for the business world. How do we bridge that gap with the areas we have little or no knowledge in?

In my veterinary business I have always felt that I needed to surround myself with people who had more experience than I. I have been very fortunate to have had many mentors who have helped me not only with my career but also my personal and family life.

What is a mentor? I recently read an article in the San Antonio Business Journal titled, “You Can’t Do It Alone” by Hilary Burns. She described a mentor as a person you can tell the good, the bad, and the ugly to, someone that you should feel comfortable sharing the intimate details of your career with. It should be someone you can trust. In my opinion it is possible to have mentors from many different walks of life and in many different stages in your life. I have an attorney who is a mentor. I have an accountant who is a mentor. My dad’s old boss has been a huge mentor especially as I got further into my career and in my life. If you are as fortunate as I am even your wife and children might be able to act as mentors in certain cases. I have many veterinarians who have also acted as mentors in my life. A good mentor to me is someone who I can be completely open with. Someone who will tell you when you are wrong or going in the wrong direction or someone who lets you know when you are doing things correctly. But also to me a mentor is someone I can learn from. That to me is the value of a mentor.

So why do we need mentors? What is the value of having mentors? There have been so many times in my career that I needed advice on something. As we struggle to balance work and family and run a business there is always a need to get an opinion from someone else. Am I making the right decision? How should I react to my employee’s wants and needs? What should I do in this situation? Surround yourself with people who can help you answer those questions. What did they do in this situation? How did they become successful? Why do you do things that way?

How often should you meet with mentors? I think this answer is different for everyone. In my veterinary study group we meet twice a year. On some of my personal mentors I try to meet once or twice a year for lunch, just to catch up and talk about things. If I have a question or a problem that I
need help with then I reach out immediately to whom I deem the most appropriate.

How did these people become mentors? As I stated earlier, I try to surround myself with people who have more knowledge and experience than me. I actively look for people who I feel would be helpful or inspirational to me. Some of these relationships have evolved over many years and started back when I was a kid. But others have come through acquaintances or people I have come into contact with through my everyday business. My advice is to always look around for people who might inspire you and/or become possible mentors.

What can a mentor offer? Especially for those of us who are in mid career or even late in our career?

2. Inspiration
How many of us have felt like quitting or felt burn-out later in our careers? A mentor can inspire you to become focused and possibly help you to remember why you chose veterinary medicine.

3. Experience
As we mature in our practice lives we start to face different problems. It might be more employees, more veterinarians, and more paperwork. A good mentor is someone who has the experience and resources to help you navigate through the different things you encounter.

4. Retirement Advice
Who do we talk to about retirement advice? What if you are the first person retiring in the practice? Someone who has been there and done that would probably have some very good advice.

5. A Pat on the Back
As I walk into my practice every morning as I have done for over 20 years, I try to come up with ways to motivate myself and keep everybody else motivated in the practice. As each year goes by I think to myself why do I do this and how do I keep a positive attitude and continue to try to make my practice flourish, change, and grow. I seek out one of my mentors and they help me realize how fortunate I am and how great a career veterinary medicine can be and what a good job I’m doing. Sometimes it is just that little pat on the back from someone you respect and trust who makes you realize what a great job you really have.

There are many reasons to have mentors and I have touched on just a few of them. But don’t be afraid to seek someone else’s help and don’t be afraid to tap into someone else’s knowledge and talent. It doesn’t matter what stage of practice you are in, it is always nice to have a mentor.

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Parenthood and Practice Transitions

Anne Marie Wilson, DVM

1. Introduction
There are a thousand questions you can ask when thinking of starting a family. When is it the right time? How am I going to work while pregnant and after with a child? Will I lose clients while on maternity leave? How much time can I take off on maternity leave? Can I afford not to work? Who will watch my baby when I am at work? How will I balance being a mom and a veterinarian? These are only a few of the concerns that immediately may come to mind. Many equine veterinarians have found ways to raise their children successfully, and each of them took a different path. All of them found ways to make it work for their families, and you will too.

Deciding when to start your family is a personal decision, but there will never be the perfect time. Things to consider are the type of practice you are in and how supportive your employer and staff will be. Has there been another veterinarian that has paved the path or will you be the first employee? It is important to review the employee handbook to know the pregnancy policy and find out the state and federal laws that may protect your job. Determining the amount of time off for maternity leave will depend on several factors such as practice policy, financial support through savings/state disability/private disability insurance, and clientele pressures.

Your ease in managing your career after becoming a parent will vary depending on your personal situation: whether you have family nearby, whether your spouse will be able to provide some of the child’s care, what type of a practice you work at and how accommodating your boss is. When you figure the economics of paying for the childcare you may find that you cannot rationalize continuing to work initially. On the other hand, you may need or want to continue your professional development right after the birth. No matter whether you decide not to go back to work short or long term, work part time, or full time you will need support from others. Your career may change directions over time to accommodate for the many responsibilities of being a parent.

Finding the right balance between your responsibilities as a veterinarian, mother/father, wife/husband, and to yourself is another very personal journey, and may change as your children grow. Nothing else can compare with having a family. It will change your perspective on life and your career. Being a parent comes with challenges, but there is nothing else more rewarding than to watch children grow. The equine veterinary industry demands that you be available 24 hours a day, which is difficult to balance with a quality family life. Again
it is important to have support from family, friends, and colleagues to help keep things in balance.

Each person who embarks on the wonderful journey of parenting follows a different path. Learn about the many ways to meet the challenges by seeking out the stories of the other equine veterinarians with children. You are sure to learn some valuable perspectives and figure out what will work for you.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.
Considerations for Veterinarians When Expanding a Family

Cassandra Shores, DVM

The decision to start a new family is not one to be taken lightly. However, when one or multiple members of this growing family are part of the veterinary field, the obstacles and challenges faced can become exponentially greater. Aside from the long hours, possible emotional fatigue and physical toll, veterinarians, specifically those focusing on all things equine, face potentially serious danger every day. Planning and instituting precautions prior to expanding a family can make the transition a much easier one and also allow the parent or parents to focus on the joy of welcoming a new member into their family. This paper is intended to assist veterinarians looking to expand their family in considering the potential challenges and precautions associated with pregnancy, maternity or paternity leave, and pumping breast milk at work.

Pregnancy while working around horses presents many challenges as they are quick, powerful, and often unpredictable animals. A once straightforward lower-limb laceration become problematic when bending from the waist and crouching are nearly impossible. Euthanasias can become a significant risk given that horses often collapse quickly and may fall forcefully to the ground, or can become excitable. Adequate sedation and proper restraint will often help to make most situations safe for everyone, but there are some dangers for both mother and fetus that should be avoided.

Radiographs are unsafe for a developing fetus; however, this does not mean a pregnant veterinarian cannot use this helpful diagnostic tool for 9 months. Instead, plan ahead, taking enough staff or recruiting extra barn help to assist with any needed radiographs. When on emergencies, most veterinarians find that many radiographs can wait until normal hours with severe fractures being the exception.

Gases from inhalant anesthesia are also potentially harmful and with no clear safe levels established, it is best to avoid these dangers whenever possible. Active scavenge systems, leak checks, and good ventilation systems can help keep anesthetic gas levels to a minimum. The National Institute of Occupational Safety and Health (NIOSH) approved chemical cartridge respirator for organic vapors, or several varieties of supplied air/self contained breathing apparatus can be used in addition to environmental precautions to minimize risk to pregnant women. NIOSH and the Occupational Safety and Health Administration (OSHA) have several recommendations for safety when using anesthetic gases.

There are many decisions pregnant veterinarians must face such as when to tell their employer and...
other staff members, when to start maternity leave, how much leave to take, returning to full- or part-time work, pumping at work, etc. All of these are personal choices with no right or wrong answer. Informing an employer sooner rather than later is typically helpful and avoids frustration for everyone when radiographs and anesthetic gases are to be avoided. Depending on your clinic’s policies and time on the job, maternity leave may or may not be paid. Employees looking to expand their family should determine whether their clinic offers paid maternity leave and assess their own financial situation beforehand. Saving vacation days can often help defray the lack of income during leave. The Family and Medical Leave Act (FMLA) allows new mothers working in companies of 50 or more employees to take up to 12 weeks of unpaid leave as long as they have been at their current place of employment for at least 1 year. Complications for pregnant mothers may also play a role and influence not only when maternity leave is started, but also other restrictions at work, such as time standing and avoiding heavy lifting.

After a breastfeeding mother returns to work and has made the decision to continue pumping while at work, the Department of Labor requires that employers allow adequate breaks for pumping and a space other than a bathroom in which to do so for employees covered under the Fair Labor Standards Act. Veterinarians are often salaried employees who are exempt from coverage under the Fair Labor Standards Act; however, the Department of Labor encourages all employers to allow for pumping at work and 27 states have laws related to breastfeeding or pumping in the workplace. The National Conference of State Legislatures’ Web site has more information for individual states.

When new mothers or fathers return to work, some opt to return at a part-time status and may or may not become full time as their infant ages. Each family will need to decide what arrangement works best for them and discuss any changes with their employer when appropriate. Although there is no right or wrong answer when it comes to expanding a family, there are many decisions and changes to be made in a small amount of time. With a small amount of planning, the transition into parenthood can be relatively easy.

**Acknowledgments**

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**References**

1. Introduction

The upper airway is defined as all respiratory structures from the nose up to and including extrathoracic trachea. The prevalence of nasopharyngeal and laryngeal dysfunction are overrepresented compared with nasal and tracheal obstruction and will be the focus of this presentation. Upper airway obstruction may affect a horse’s performance or quality of life by interfering with ventilation during inhalation or exhalation. Alternatively, a change in airflow pattern or airway wall collapse may result in an abnormal upper respiratory noise. It is important to note that the presence and intensity of the abnormal noises are not always correlated with the degree of airway obstruction.

Depending on the gait of the horse and exercise intensity, the horse can use three breathing strategies to compensate for an impairment to its ventilation as listed below:

1. Increase its driving inspiratory pressure
2. Uncouple its gait and respiratory frequency (normally a 1:1 ratio)
3. Change the duration of its inspiratory and expiratory time (i.e., prolong the time available for inhalation as seen during laryngeal collapse).

With continued exercise in the presence of resistive breathing, the change in flow pattern and perhaps muscle fatigue can lead to further soft tissue collapse and even pulmonary damage. Another facet suspected by many trainers/owners/veterinarians is that the horse learns to anticipate an anoxic event and modify its performance accordingly. This “behavior” is difficult to identify and quantify let alone separate from the effects of the actual ventilation compromise.

We must first identify and recognize the clinical problem. It should be noted that 30–43% of horses experience multiple obstructions (i.e., comorbid obstructions). These may be co-existing disease or induced collapses because of changes in pressures and flow dynamic caused by the obstruction. Therefore, it is especially important to fully identify all the obstructions so that the management/treatment can be tailored appropriately to the patient.
This review will use preferentially evidence-based data in horses with naturally-occurring disease when available. Data resulting from high-level evidence-based clinical trials gives us the best guidance on how to clinically approach a problem. Unfortunately, this body of clinical evidence is limited in many fields of veterinary medicine and that is certainly true in this area of specialization. When high-level evidence base is lacking, data from experimental models is also of value to quantify the various tests and treatments to give us guidance in the management of horses with upper airway obstructions. Information on which diagnostic method or treatment is preferable can be answered based on determination of the airway mechanics or frequency analysis of abnormal sounds. However, extrapolations from experimentally-created disease in normal horses to horses with naturally-occurring disease performing different athletic functions may not be fully appropriate. Experience from trial and error will modify this guidance. It is hoped that over the years more evidence-based data will replace this “softer” guidance. In addition, both the recognition and the treatment remain an “art”. For example, a Grade 4 laryngeal hemiplegia is a seemingly simple and clear description of recurrent laryngeal neuropathy (RLN). However, upon inspection of three cases of RLN (Fig. 1), marked differences become obvious and the degree of interference with ventilation differs. The horses in Figure 1, A and B were asymptomatic at rest whereas the horse in Figure 1C was dyspneic at rest.

The author hopes to properly pay tribute to the many authors of papers and presentations during the last few years that have greatly increased our understanding in the diagnosis, pathophysiology, and management of upper airway dysfunction in horses. This review will also be in line with recent recommendations to clean up the various terms that have been used through the years but are not consistent with the proper Nomina Anatomica Veterinaria and yet have been pervasive in the veterinary literature.6

2. Diagnosis

History

Horses with upper airway obstruction may have a history of poor performance and/or abnormal upper respiratory noise. The degree of poor performance subjectively plays a role in influencing treatment. A racehorse with decreased, yet still satisfactory performance may be treated less aggressively than the same horse that is finishing 48 lengths behind. Remember to extend the history and the examination beyond concern for upper respiratory obstruction. Hypoxemia from lower airway disease or cardiac arrhythmia is likely to render the upper airway more collapsible and should be addressed.

The abnormal noise can happen during inspiration, such as in horses with dynamic laryngeal collapse, or expiration (more characteristically described as gurgling).7,8 Although abnormal upper respiratory noise is a reasonably sensitive test (80−84%) for obstruction of the upper airway, it has a very low specificity (25%).7–10 The specificity might be higher except that a percentage of horses (20−30%) are silent despite the presence of an upper airway obstruction.7,8,11 In addition, many horses have more than one obstruction so the abnormal upper airway noise is not specific.7–10

While gathering a medical history, getting information on the head position and influence of the degree of poll flexion on noise production is important. In sport horses, poll flexion has been reported to be important in recreating the abnormal upper respiratory noise and is one of the reasons why overground endoscopy (OGE) is the gold standard in those horses doing this activity.9,12–14

Fig. 1. Endoscopic images of (A) a 3-year-old Thoroughbred colt, (B) a 3-year-old Thoroughbred filly, and (C) a 3-year-old male castrated Belgian, all affected by recurrent Grade 4 left laryngeal neuropathy. Note the different degrees of medialization of the left arytenoid cartilage.
Gurgling noise (i.e., also described as snoring or a rattling noise) during exhalation is reported in horses with soft palate displacement. It has been associated with fluttering of the caudal free edge of the soft palate displacement. Franklin et al., 2004 reported that the highest amplitude of frequency associated with soft palate vibration in horses ranges from 50–150 Hz. By inspection, we have observed that some horses have marked fluttering of the caudal edge of the soft palate whereas in others the palate billows up and down at the respiratory frequency (~2 Hz). This can be variable during the exercise intensity given that generally more fluttering is heard as the horse’s exercise intensity decreases. This may explain “silent displacers” and horses in which the noise is only heard when the horse pulls up. It is worth noting that because complex (i.e., multiple co-existing) obstructions are common, additional noises of alar folds fluttering, palate billowing, and medial deviation of the aryepiglottic folds would “muddle” the characteristic “gurgling” noise.

The noise described with vocal cord and/or arytenoid collapse is also a common abnormal noise and has been described as “whistling” or “roaring” and is heard during inhalation. Spectrum analysis of this noise has revealed three frequency bands centered around 300 Hz, 1.6 kHz, and 3.8 kHz. These latter reports were done in horses with experimentally induced left laryngeal hemiplegia and therefore some slight differences can be expected in a clinical population. The range of intensity of sounds would be different and degree and onset of collapse would be quite variable in a clinical population.

In summary, the absence of noise is not an assurance of a fully patent airway and the aforementioned noises are suggestive of the cause of the abnormal sounds but are neither a perfect nor a complete indicator of the full spectrum of airway compromise or whether surgery is or is not needed.

Physical Examination

The basis of an upper airway examination is to perform a thorough evaluation of the upper airways. This starts with assessment of the presence or absence of drainage at the nostrils. A critical evaluation is to assess the symmetry of the airflow: although masses/enlargements of the sinuses or ventral or dorsal conchae are a common cause of airflow obstruction, one cause that can be missed is horses with Horner syndrome. Although the typical sign of Horner syndrome is sweating rostral to the site of lesion of the sympathetic nerve, we have found that the sweating at rest seems to resolve earlier than the sympathetic dysfunction of the nasal capillary bed. The resulting loss of tonic sympathetic tone can result in ipsilateral vascular engorgement of the nasal turbinates occluding most of the airflow. A clinical feature that, in the author’s experience, has been quite reliable is the vertical position of the eyelashes (Fig. 2) compared with the unaffected contralateral side. This is associated with enophthalmos and prolapse of the third eyelid seen with Horner syndrome. External assessment of the external bony contour of the head and sinus is important to perform to identify fixed obstruction created by mass or fluid enlarging the sinus.

The laryngeal cartilages should then be palpated to identify laryngeal structural malformation and cysts. One should specifically assess and compare the left and right thyroid lamina as well as the cricothyroid spaces, which are generally abnormal in cases of laryngeal dysplasia or fourth branchial arch defect. The affected side, usually the right side, has a larger cricothyroid space and a more elevated dorsal extension of the thyroid cartilage that “feels” like a smaller muscular process. Both jugular veins should be palpated for patency and enlargement given that jugular thrombophlebitis may be associated with vagal and recurrent laryngeal nerve injury. The cricoarytenoid dorsalis (CAD) muscles should then be palpated for evidence of atrophy. Most textbooks describe palpation of the left and right muscular processes to identify atrophy of the CAD. However, in the author’s experience, palpation of the caudal aspect of the cricoid is more sensitive because of the factors listed below:

1. The cricopharyngeus muscle is not overlying the target area as it is with the muscular process
2. The muscle compartment palpated on the caudal aspect of the cricoid cartilage is the caudolateral compartment of the CAD, which is more affected with atrophy in horses with RLN

Upper respiratory dysfunction is not only a concern of airway patency (i.e., respiratory), it is also a con-
cern of the integrity of the protective mechanism of the larynx (i.e., deglutitive). Dysphagia, esophageal reflux, or laryngeal and/or nasopharyngeal incompetence may all result in penetration of feed and water into the trachea and may lead to lower airway infection and pneumonia. Once it is recognized that tracheal aspiration is occurring, one should also evaluate the lower airways and evaluate systemic signs of infection.

Resting Endoscopy

**Generic Respiratory Examination**

Resting endoscopic examination is the standard and is most commonly used as a diagnostic aid to assess patency and abnormalities of the upper airways. The examination is performed with or without a nose twitch or lip chain and preferably without sedation. Many authors have emphasized that sedation may interfere with the evaluation of laryngeal function in horses.22–24 Sedation with xylazine hydrochloride, detomidine hydrochloride, or acepromazine maleate can affect the symmetry of the movements of the arytenoid cartilages, predominantly by decreasing the abduction of the left arytenoid.24 In addition, abnormalities such as nasopharyngeal collapse are difficult to reliably identify from resting examination after sedation. In the author’s experience, sedation can also lead to a worsening of a clinical nasopharyngeal collapse and can also lead to a false diagnosis. Therefore, the nasal passage, nasopharynx, larynx, and extrathoracic trachea are best examined with the animal unsedated. Fixed obstruction such as masses, cysts, arytenoid chondritis, persistent dorsal displacement of the soft palate (pDDSP), and epiglottic abscess can be readily assessed. Dynamic obstruction such as nasopharyngeal collapse, palatal instability, and intermittent dorsal displacement of the soft palate (iDDSP), and various forms of laryngeal collapse are more difficult to identify and their significance is much harder to characterize based on a resting exam.

Epiglottic retroversion and tracheal collapse are two abnormalities that can sometimes be suspected from resting endoscopy although they can only be confirmed by exercising endoscopy or dynamic imaging. Epiglottic retroversion can be suspected in horses in which the epiglottis is more dorsal than normal and close to the roof of the nasopharynx (Fig. 3). Tracheal collapse can be suspected if it occurs during endoscopic exam of the extrathoracic trachea or if it can be induced with simultaneous palpation of the larynx. (Note: Radiographic assessment can also detect tracheal collapse on radiographs: See Imaging Digital Radiography section).

Guttural pouch examination is also important to perform given that disease in this area can affect the neural function of the vagal and glossopharyngeal nerves, which affect the stability of the upper airways.25–27 Guttural pouch empyema, mycosis, and enlargement of the nasopharyngeal lymph nodes can all interfere with the vagal, pharyngeal branch of the vagus, hypoglossal, or glossopharyngeal nerves. Neuritis and/or neuropraxia of these nerves leads to collapse of the nasopharynx, dysphagia, and/or pDDSP. Guttural pouch tympany is another cause of collapse of the roof of the nasopharynx without inflammatory disease in the guttural pouch.28–30 Finally, endoscopy should evaluate the size of the stylohyoid bone and the mobility of the temporohyoid articulation.31–33 Although temporohyoid osteoarthropathy (THO) is best evaluated using computed tomography (CT), enlargement of the stylohyoid bone especially in its proximal section would suggest THO.

**Palatal Problems**

Palatal abnormalities may be structural (i.e., cleft and palatal cyst) of functional iDDSP. Congenital cleft palate can be observed to be on the midline or assymetrical.34–36 The tip of the epiglottis can be observed with the endoscope looking ventrally at the level of the cleft. Oropharyngeal mucosa and palatine tonsils can be readily seen. Lower airway evaluation is very important to decide whether the cleft needs to be repaired and what the proper delay is before treatment.34,35,38 Palatal instability and iDDSP are both very common causes of airway obstruction and abnormal upper airway noise during exercise. Diagnosis of iDDSP based on endoscopy has a very low diagnostic accuracy when performed based on a resting examination.7,39–41 Dorsal displacement of the soft palate (DDSP) seen during resting endoscopy, considered with the positive history of making a noise during exercise, was only correct in predicting
DDSP in 50% of cases. Identification of ulcer on the caudal free edge of the soft palate may be an indication of iDDSP but is also observed with subepiglottic ulcer/ granuloma, and intermittent epiglottic entrapment. Flaccidity of the epiglottis and induced DDSP by swallowing or by nasal occlusion is not reliable evidence of DDSP given that these are seen also in nondisplacers during exercise. When DDSP is induced, one can observe the caudal aspect of the soft palate not only for the presence of ulcers, cysts, and granuloma but also evidence of prior staphylectomy (Fig. 4).

Resting identification of persistent DDSP (pDDSP) is reasonably accurate. The exception is in some horses, which will have been induced to displace and will not replace their soft palate until the twitch is removed. The examination should then proceed toward identifying the cause of the displacement: is there pain in the nasopharynx or laryngeal area? Look for evidence of denervation to the nasopharyngeal musculature, and structural abnormalities such as subepiglottic and palatal cysts, or acute or chronic epiglottitis.

The author uses the DDSP grade in Table 1 to categorized status of the soft palate on resting endoscopy (Table 1).

### Table 1. Soft Palate Grade on Resting Nasopharyngeal Endoscopic Examination

<table>
<thead>
<tr>
<th>Soft Palate Grade</th>
<th>Endoscopic Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>DDSP is not present and cannot be induced by endoscopic penetration of trachea or induction of swallowing.</td>
</tr>
<tr>
<td>1</td>
<td>DDSP is not present but can be induced by endoscopic penetration of trachea or induction of swallowing. One or two swallows is needed to replace the soft palate.</td>
</tr>
<tr>
<td>2</td>
<td>DDSP is not present but can be induced by endoscopic penetration of trachea or induction of swallowing. Multiple swallows (&gt;2) are needed to replace the soft palate.</td>
</tr>
<tr>
<td>3</td>
<td>Persistent DDSP: epiglottis can be occasionally observed.</td>
</tr>
<tr>
<td>4</td>
<td>Persistent DDSP: epiglottis is not observed.</td>
</tr>
</tbody>
</table>

Note: the author considers Grade 2–4 to be more likely to indicate clinical disease and Grade 0–2 within normal limits.

Recurrent Laryngeal Neuropathy

RLN is the most common cause of laryngeal hemiplegia or arytenoid and/or vocal cord collapse during exercise. The value of a resting grade is to have a system that can reliably describe the findings of a resting exam in relation to laryngeal respiratory function. A significant amount of work focuses on the correlation of resting laryngeal grade at rest compared with exercise. The original proposed four-grade system was further refined during the 2003 Havemeyer workshop (Table 2). How useful is this laryngeal grading system beyond describing to others the apparent status of the laryngeal function? A few recent studies have looked at the predictive value of the four broad resting laryngeal grades in racehorses. Horses with a laryngeal Grade of I and II are associated with good performances. Clearly, however, not all horses with laryngeal Grade III have laryngeal collapse during exercise nor do all laryngeal Grade I and II show the absence of laryngeal collapse. Barakzai and Dixon correlated the resting Havermeyer laryngeal grade with exercising grade in 272 horses. They reported that 96% and 92% of laryngeal Grade I and II, respectively, did not have laryngeal collapse whereas only 34% of laryngeal Grade III had full laryngeal abduction. Garret et al, 2010 also emphasized the value of the Havermeyer laryngeal sub-grade in a study of 2954 yearlings at sales. Yearlings with laryngeal sub-grade of II.2 had lower earnings than horses with a laryngeal grade of I or II.1. The value of the laryngeal sub-grade in Grade III horses was showed by Barakzai and Dixon. Indeed, horses given a Sub-grade III.1, III.2, or III.3 had good correlation with increasing collapse during exercise (Grade A, no collapse; B, partial collapse; and C, collapse) medial to neutral position of arytenoid (ρ = 0.43; P = .0017).

The aforementioned data focuses on correlation of laryngeal collapse during exercise with resting endoscopic findings. Yet what is the correlation with actual RLN? This was explored by a few authors. Horses with decreased abduction of the left arytenoid have the typical neuromuscular signs associated with distal axonopathy, which is progressive denervation with evidence of reinnervation. It was first reported that in all horses evaluated,
there was histopathological evidence of left RLN even in horses with resting laryngeal Grade I and exercise Grade A. Collins et al, 2009 demonstrated a statistically significant correlation between the severity of the histopathological muscle assessment of the left CAD and the Havemeyer laryngeal grade and sub-grades. In summary, the well-defined, and universally adopted Havemeyer resting laryngeal grade (Table 2) allows a fair and validated description of the status of a given horse's respiratory laryngeal function at the time of examination. It broadly and ipsilaterally correlates with the RLN disease process (with the caveat that all horses may have the disease), and has fair prediction of laryngeal collapse during exercise. It is worth noting that the laryngeal ultrasound dichotomized assessment (i.e., normal vs abnormal) of the echogenicity of the cricoarytenoid lateralis (CAL) muscle has a better sensitivity and specificity and is therefore likely a predictive value of laryngeal collapse during exercise. However, laryngeal ultrasound should not replace the resting assessment of the larynx given that the luminal side of the larynx is not well evaluated with laryngeal ultrasound. Small or localized luminal side arytenoid chondromas, arytenoid subluxation, and abnormal movements of the arytenoid cartilage are likely to be missed on laryngeal ultrasound, not to mention all other important anomalies such as DDSP, epiglottitis, epiglottic abscess, sub-epiglottic ulceration, postsurgical assessment, etc.

Table 2. Laryngeal Grade on Resting Endoscopy From the Summary of the Havemeyer Meeting held 7–10 September 2003 in Strafford-Upon-Avon, United Kingdom

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Sub-Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>All arytenoid cartilage movements are synchronous and symmetrical and full arytenoid cartilage abduction can be achieved and maintained.</td>
<td>1. Transient asynchrony, flutter or delayed movements are seen. 2. There is asymmetry of the rima glottidis much of the time due to reduced mobility of the arytenoid and vocal fold but there are occasions, typically after swallowing or nasal occlusion, when full symmetrical abduction is achieved and maintained.</td>
</tr>
<tr>
<td>II</td>
<td>Arytenoid cartilage movements are asynchronous and/or larynx asymmetric at times but full arytenoid cartilage abduction can be achieved and maintained.</td>
<td>1. There is asymmetry of the rima glottidis much of the time due to reduced mobility of the arytenoid and vocal fold but there are occasions, typically after swallowing or nasal occlusion, when full symmetrical abduction is achieved but not maintained. 2. Obvious arytenoid abductor deficit and arytenoid asymmetry. Full abduction is never achieved. 3. Marked but not total arytenoid abductor deficit and asymmetry with little arytenoid movement. Full abduction is never achieved.</td>
</tr>
<tr>
<td>III</td>
<td>Arytenoid cartilage movements are asynchronous and/or asymmetric. Full arytenoid cartilage abduction cannot be achieved and maintained.</td>
<td>1. Transient asynchrony, flutter or delayed movements are seen. 2. There is asymmetry of the rima glottidis much of the time due to reduced mobility of the arytenoid and vocal fold but there are occasions, typically after swallowing or nasal occlusion, when full symmetrical abduction is achieved and maintained.</td>
</tr>
<tr>
<td>IV</td>
<td>Complete immobility of the arytenoid cartilage and vocal fold.</td>
<td></td>
</tr>
</tbody>
</table>

Description generally refers to the left arytenoid cartilage in reference to the right. However, this grading system can apply to the right side (i.e., right Grade III-1).

Generic Deglutitive Examination

Resting evaluation of the protective mechanism of the larynx is another important value of endoscopy. Dysphagia is observed in neonatal foals with apparent nasopharyngeal “immaturity,” with congenital or acquired cleft palate, following guttural pouch diseases with extension of the disease or surgical trauma to adjacent peripheral nerves. Dysphagia is also reported as a complication of various upper-airway surgical procedures such as staphylectomy, arytenoidectomy, and laryngoplasty (Table 3). Dysphagia is broadly described as nasal regurgitation of feed material or water and tracheal aspiration of feed material. Equine practitioners have been increasingly frequently asked to treat horses with swallowing disorders/dysphagia. Its true definition is passage of food, saliva, secretions, and/or liquids past the vocal folds into the extrathoracic trachea. The author has observed (no doubt as have others) that the site of aspiration is different in horses with a cleft palate compared with that seen after a laryngoplasty or arytenoidectomy. Furthermore, dysphagia after laryngoplasty may be in our estimation due to the following:

1. Failure of the arytenoid cartilages and vocal fold to meet on the midline to protect the trachea
2. Predominant scarring of the left dorsolaryngeal area that prevents laryngeal elevation
and thus proper epiglottic retroversion to protect the trachea (these horses are more likely to respond to laryngeal tie-forward in our experience).

3. Esophageal regurgitation (because of damage to the cranial-esophageal sphincter or fibrosis involving the esophagus causing a simple obstruction)

The goal of endoscopy during swallowing is to identify the mechanism or site of respiratory integrity incompetence. These sites are defined as either oropharyngeal-to-nasopharyngeal aspiration, oropharyngeal-to-tracheal, and upper esophageal regurgitation. This is an emerging field for surgeons and has been observed with and without any prior surgical intervention. Barium swallows are of value in identifying those yet they are less readily available so the endoscopic swallowing test is used more often.

Typically, the horse is fasted overnight to ensure a good appetite. The endoscope is placed through the right nasal passage and secured to the horse halter as performed for treadmill endoscopy (alternatively, an overground endoscope can be used). The horse or foal is then fed at the height at which the aspiration or coughing is reported. In foals, the endoscopy is performed while it nurses on the mare as that is when the aspiration is most common. In adult horses, it is at shoulder height. During barium studies, the horse forms a bolus in the caudal aspect of the nasopharynx, caudal to the base of the tongue which is detected by elevation of the caudal aspect of the soft palate. During swallowing, this bolus is elevated over the closed larynx (by the combination of laryngeal elevation and epiglottic retroversion, adduction of the vocal folds and arytenoid cartilages with the lateral aspect of the larynx being sealed by the ary-epiglottic folds). The above three sites of laryngeal competency can then be evaluated as well as the three mechanisms of laryngeal closure. In severely dysphagic cases, only one or two swallows can be observed given that after contamination assessment of its source may be prevented. In addition to looking for the site of the feed penetration, one should confirm and evaluate the following critical sites:

1. Verify that the epiglottis is indeed retroverting properly. This is determined by observing the epiglottis fully covering symmetrically the arytenoid cartilage and “coming back down” at the end of the swallowing phase as the nasopharyngeal constriction is released.

2. Proper midline contact of the vocal fold and arytenoid cartilage (Fig. 5, A–C) is occurring.

3. Esophageal reflux is not occurring (Fig. 6).

Dynamic Endoscopy

Fixed airway obstruction resulting in resistive breathing can generally be identified by external examination of the upper airway and by resting endoscopy. Many obstructions occur only or more markedly during exercise because of one or more of the following: increased respiratory pressures, increased respiratory frequency, and decrease inspiratory and expiratory times associated with exercise. The reduction in airway geometry results in changes in kinetic energy, velocity, and turbulence in the airway which results in secondary collapses. Therefore, an airway obstruction may change airflow pattern and wall-pressures and explain why secondary collapse may also be observed and have been reported in nearly 50% of horses.

Dynamic endoscopy is an important diagnostic test to allow recognition of dynamic collapse or to confirm the absence of airway obstruction. Dynamic endoscopy during exercise was first performed using standard flexible videoendoscopes with horses exercising on a high-speed treadmill (HSTE) (HST). This form of dynamic endoscopy was first popularized by clinicians at Tufts University in the 1980s. Many other equine clinicians have performed those dynamic exams as it became the gold standard for the diagnosis of upper airway abnormalities in horses. It remained the gold standard probably until a few years after the introduction of commercially available overground endoscopes (OGEs). The advantages of HSTE are that the protocols are well established leading to a maximal or near-maximal exercise intensity. In
addition, HSTE allows additional physiological parameters to be monitored such as EKG, echocardiography, lameness, gait disturbance, and pulse oximetry. Finally, a key point is that the desired exercise intensity is decided by the team doing the examination and not the trainer/owner.

In 2008–2009, Tamzali et al, Desmarizieres et al, and Pollock et al, introduced OGE. OGE offers an even closer approximation of upper-airway morphology and function during exercise/competition. This is because it allows the head position, action of the riders (including jockeys and drivers), presence of the sulky, and subjective elements of competitions (i.e., grounds, temperature, environments, adjacent horses, etc.) to be reproduced. This approximation to the exercise intensity in competition became even closer when OGE was performed during qualifying races. Both dynamic endoscopic techniques (HSTE and OGE) are preferable to diagnosis solely made based on resting endoscopy. Indeed, numerous studies have reported the low correlation of resting endoscopy and dynamic endoscopy regardless of whether the exam was performed on HST,4,7,40,42 or overground14,96,102 or both. How do we compare the value of dynamic exam during HST vs overground? The strength of overground examinations are obvious and have been well described. They “should” most closely resemble the situation during the competition or athletic competition. However, as pointed out by Allen et al, 2010, the distance that flat Thoroughbred racehorses are tested at is not always (or perhaps more accurately not often) as long as they are during their last race. Unlike the situation during HSTE, the trainer has a strong (if not full) control of the intensity and duration of the exercise test. The author finds that it is often the trainer’s desire to add endoscopy (i.e., OGE) to the programmed training session (i.e., length and intensity of the horse’s workout), rather than program the exercise test that best simulates the racing conditions. To be sure, this is usually due to the trainer’s important priorities listed below:

1. Prevent injury to the horse
2. Consider the horse’s most recent training effort

Fig. 5. A 4-year-old Thoroughbred with chronic tracheal aspiration following a left laryngoplasty and “modest” ventriculocordectomy performed 2 years prior. A, Dixon Grade 3 abduction with tracheal contamination, B, representative views of maximal closure of the ventral aspect of the larynx. The vocal process of the right arytenoid (black arrow) is the leading edge of the closing (i.e., adductory) action. C, Note that the vocal folds do not make contact with each other during adduction.

Fig. 6. A horse that has esophageal reflux during exercise. This is representative of reflux at rest after a swallow.
3. Use the exercise intensity that leaves the horse on track to perform its next race

This typically results in exercise tests that are of lower intensity (speed, duration or both) than those experienced during competition. Allen and Franklin 2010,103 reviewed exercise protocols in the United Kingdom noting that the detection of some upper airway abnormalities, specifically iDSSP, requires strenuous exercise and therefore have been easier or more frequently detected (i.e., accurately) during treadmill examination.82 In that aforementioned review, the authors found that the total over-ground exercise test was quite variable (800–6100 m), some in straight gallop and others in circular gallop), some on the flat and some on the incline. The peak speed achieved in those over-ground tests were slower than those during racing. In the author’s experience, these results are quite representative of the obstacles and the main weakness of the over-ground test. The OGE exercise tests are closer to the situation experienced during racing/competition in all aspects except in regard to exercise intensity. It has been found that only the lower limits of an OGE exercise test can be reliable set. The minimally acceptable limits (unless the horse experiences clinical signs very early during the competition) under which we will perform the test varies for flat racehorses vs trotters/pacers. In Thoroughbred racehorses we only do an examination if the horse is exercised at least 5 furlongs (1200 m) and preferably in company. In harness horses, the minimal distance of the test is 1600 m. If the minimal exercise protocol is not defined, the veterinarian is liable to make false-negative conclusions in regard to the status of the upper airway (miss a diagnosis of DDSP or palatal instability)82 or underestimate the degree of laryngeal collapse.

As previously reported, injury rates are very low during both HSTE4,104 and OGE,105,106 although the perception is that HSTE has more risks.87 Injuries occur during both types of examinations (HSTE and OGE) associated with exercise intensity. On the treadmill, additional risk is present to the horse if it tries to jump off, but in practitioners’ experience of thousands of horses, this is extremely rare. It has been observed that the injury rate is very low with proper protocol and the most common (if not only injury) are minor hoof injuries related to losing a shoe during exercise. During overground endoscopy, the added injury risk is to the rider/driver and this is also very rare.88

In the author’s practice we use both HST and OGE but do not do both examinations on the same horse. Because of the affect of head positions and poll flexion collections in sport horses, OGE examinations are preferred in all horses that perform those activities. Thoroughbred racehorses are examined preferably with OGE unless a more complete examination (i.e., including a lower airway and/or cardiology exam) is medically indicated, then an HSTE is performed. We believe that the diagnostic value of dynamic endoscopy is equivalent in Thoroughbred racehorses regardless of whether HSTE or OGE is used as long as criteria for exercise intensity are respected. In trotter/pacers because of the higher prevalence of co-existing morbidity (requiring additional physiological testing), we believe that HSTE is preferred.

Imaging

Digital Radiography

Imaging of the upper airways has,107–111 been used for years to assess the patency of the nasal passage and the influence of paranasal sinus diseases on the airway. Standard lateral, lateral oblique, and the dorsoventral radiographs (probably the most useful view) are used for assessment of patency and to define the geometric abnormalities of the nasal passages. High-definition endoscopy is more accurate to assess patency of the upper airway but obstructions may be further defined by radiography although CT scans and magnetic resonance imaging (MRI) are the most complete modalities for that latter purpose.

Radiographs of the nasopharynx have been used to assess the diameter of the nasopharynx with various head positions,100,112 and the position of the larynx in relation to the nasopharynx,94,113,114 and other general assessment of those two areas.115 The relationship between native epiglottic length and prevalence of DDSP is no longer viewed as having much clinical significance.41 However, this modality is used most commonly to assess the anatomical location of the larynx post laryngeal tie-forward. For that purpose, the head is placed in an extended position.113 Objective measurement of the position of the center of the lateral aspect of the basihyoid bone, the ossification in the thyroid cartilage, and the thyrohyoid bone junction to the thyroid lamina have been described.94,113 It is well established that the laryngeal tie-forward procedure moves the basihyoid caudally and dorsally and the larynx dorsally and rostrally. By inspection, the laryngeal tie-forward procedure is determined to be appropriate or satisfactory if the center of ossification of the thyroid cartilage is rostral to the thyrohyoid bone and the epiglottis overlaps the stylohyoid bone on the lateral view of the area.

Radiography of the tracheal larynx is not commonly performed and is really limited to lateral radiographs.116 It has been shown that unlike dogs and humans, the timing of the radiographs in reference to the respiratory cycle is not as important as at rest; the trachea during exhalation vs inhalation is similar. The laryngeal and tracheal dorsoventral diameters of the normal trachea in Thoroughbreds has been reported.116 Lateral radiographs of the extra thoracic trachea can thus be used to assess tracheal collapse on that plane.117 Collapse from
side to side has been observed and is not detected by this lateral cervical view of course.

Ultrasound Examination

Upper airway endoscopy, whether it be performed at rest or exercise, gives an assessment of the respiratory function of the nasopharynx and larynx. Structural assessment of the laryngeal cartilage and supportive muscles must be done through imaging. The normal ultrasonographic anatomy of the equine larynx was first described by Chalmers et al in 2006. Chalmer’s paper describes four acoustic windows to get a complete examination of the larynx:

1. Rostroventral window: to image the basihyoid, lingual process and area rostral to those structures. That window was used in reference for cases of localized swelling or to assess involvement of the ceratohyoid bone in horses with epiglottic retroversion (lesion to hypoglossal nerve(s)) or THO
2. Mid-ventral window images of the area between the thyroid cartilage and the basihyoid bone: this is helpful in assessment of whether the sutures from a prior tie-forward are tight (Fig. 7) or to guide laser treatment of the thyroepiglottic articulation
3. Lateral window (Fig. 8) showing the relationship between the cricoid, thyroid, and arytenoid cartilage as well as the CAL and cricothyroideus muscle (CTh)
4. Caudoventral window at the thyroid notch (cricothyroid space) allow imaging of the vocal folds

After that study, our team started to perform laryngeal ultrasound to better define and characterize the arytenoid cartilage and unusual swelling (Fig. 9, A and B) or chondritis (Fig. 10, A and B). Indeed, laryngeal ultrasound gives the clinicians knowledge of the proper cartilage anatomy (shape and thickness) and the ability to detect changes from what is normal. With regard to the larynx, the exam is facilitated by the fact that the contralateral side can serve as control (unless of course the horse has bilateral disease). Garrett et al, 2013 described that the features of arytenoid chondritis in the horse increased cross-sectional area view from the lateral window both in the longitudinal and transverse

Fig. 7. Mid-rostral acoustic window showing the area between the rostral aspect of the thyroid cartilage (TH) and the caudal aspect of the basihyoid (BH).

Fig. 8. Lateral acoustic window of the larynx of a 3-year-old Thoroughbred colt exhibiting normal laryngeal anatomy. TH, thyroid cartilage; CAL, crico-arytenoideus lateralis muscle; CTh, cricothyroideus muscle; Cr, cricoid cartilage; AR, arytenoid cartilage. Dotted line indicates the width of the CAL. (Courtesy of Dr. Amy Yeager, Cornell University).
planes, abnormal shape when compared with the contralateral side, small hyperechogenic foci (presence of gas) within the cartilage, and luminal masses can be seen.\textsuperscript{118} This is consistent with surgical findings, and the value in cases of arytenoid chondritis is to identify those with nondefinitive enlargement of the arytenoid cartilage or to identify abscess that would guide the treatment toward drainage as opposed to partial arytenoidectomy.

Differences in echogenicity in the CAL muscle in horses with RLN and the contralateral (presumably normal) side were noted. That same observation was confirmed in two separate studies.\textsuperscript{54,55}

It is logical since both the CAD and the CAL are innervated by the ipsilateral recurrent laryngeal nerve. With the naturally-occurring RLN or with trauma/damage to the recurrent laryngeal nerve, both muscles are subjected to denervation atrophy. This is perhaps because innervation to the CAL is longer than to the CAD; histopathological evidence of denervation is more severe in the CAL (an adductor muscle) that the CAD muscle.\textsuperscript{119,120} Therefore, the status of the CAL muscle should be a good surrogate of the evaluation of the CAD muscle (i.e., be able to identify the disease earlier or easier as atrophy is more severe) whose deficit is actually responsible for the laryngeal collapse.

Both groups who reported on laryngeal ultrasound in diagnosis of RLN expected originally that the cross-section and/or width of the CAL (Fig. 8) of the horses affected by RLN, and thus subjected to denervation atrophy, would be smaller.\textsuperscript{54,55} How-

Fig. 9. A 3-year-old Thoroughbred filly presented for failed tie-back 4 months after surgery. A, Endoscopic view showing swelling at the site of prior ventriculectomy. B, Ultrasound view showing a fluid cyst is the source of the swelling. TH, thyroid cartilage; Cr, cricoid cartilage; AR, arytenoid cartilage. (Courtesy of Dr. Amy Yeager, Cornell University).

Fig. 10. Ultrasound images (lateral windows) of the larynx of a 3-year-old Thoroughbred colt with left-sided arytenoid chondritis: Notice the marked enlargement of the body of the left arytenoid cartilage compared on the left lateral window (A) compared with normal echogenicity on the right lateral window (B). TH, thyroid cartilage; CAL, crico-arytenoideus lateralis muscle; CTh, cricothyroideus muscle; Cr, cricoid cartilage; and AR, arytenoid cartilage. (Courtesy of Dr. Amy Yeager, Cornell University).
ever, this was not the case presumably because denervation of the CAL is also accompanied by denervation of the ipsilateral CAD and therefore arytenoid cartilage medialization with a fixed thyroid cartilage occurs resulting in an increase in width of the CAL. This increase echogenicity has a high predictability for laryngeal collapse during exercise. Indeed, when the specificity and sensitivity of the detection of increased echogenicity on predicting some degree of laryngeal collapse ranged from 90–95% and 95–98%, respectively.31,121

The reason for the increased echogenicity of the CAL muscle in horses affected with RLN was recently evaluated by Chalmers et al. 2016.121 In this paper, the authors correlate the histopathological findings to the ultrasonographic appearance of 28 horses that were subjected to experimental transection of the right recurrent laryngeal nerve. Two important findings were reported in this study. The first clinically relevant finding was that the increase in echogenicity did not occur until 4 weeks after transection and this finding was only minimally apparent. For a nonimagist it may be more reasonable to assume that detection of RLN by laryngeal ultrasound will not be evident until closer to 8 weeks postdenervation. What is the relevance for this? If increased echogenicity is detected, then the denervation is probably at least 4 weeks in duration. Therefore, if one is exploring if an RLN could have been caused by a missed jugular vein injection or cervical surgery within 4 weeks, then laryngeal ultrasound indicating increased echogenicity would be evidence of pre-existing RLN. The other importance of Chalmers’s paper is the explanation for the increased echogenicity. It is first due to reduction in muscle fiber diameter (increasing the number of acoustic barriers i.e., beam-angle deflection) and at an increase in collagen content per unit area as described in other species.31,122,123 At least over a 28-week period, increase of fat content in the CAD muscle is minimal in horses.31

Esophageal ultrasound more recently gives one the ability to directly evaluate the muscle responsible for the deficit in laryngeal abduction and laryngeal collapse during exercise—the CAD muscle. This modality was first used in a research cooperation on the use of functional electrical stimulation in the equine upper and lower airways (University of Guelph, University of Liverpool, Royal Veterinary College, Maisonn-Alfort, Hackensack University Medical Center, and Cornell University). In an experiment of acute denervation of the hemilarynx, Chalmers et al, 2016 was able to also correlate increased echogenicity of the denervated CAD compared with the control side.121 It is well known that denervation reduced muscle mass on a cross-sectional area and this is associated with a loss of force-generating capacity.124–129 As expected, experimentally denervated laryngeal muscle decreased muscle volume.31,131 The investigators in the above collaboration looked at a way to measure CAD muscle volume after 12 weeks of acute denervation, first using computed tomography.131 and were able to measure a 30–40% decrease in volume in the ipsilateral denervated CAD. However, standing CT was not readily available in North America (unlike in the UK) and laryngeal ultrasound was a more practical test. The correlation between CAD volume, transesophageal ultrasound (TEU), and laryngeal function was evaluated.132 First, the correlation between ex-vivo muscle volume measurements and those measured by CT volumetric reconstruction proved to be very close (P < .0001, R2 = 0.76).132 Ex-vivo muscle volume measurements also significantly correlated with mid-body thickness of CAD measured using TEU of the CAD, albeit a lower correlation (P = .002; R2 = 0.44).132

However, the experimental data needed to be correlated with measurement in naturally-occurring RLN. From clinical experience we know that horses with naturally occurring RLN also have varying degrees of atrophy. Using a clinical population of 90 horses presented for upper airway evaluation at Cornell University with both dynamic endoscopy and TEU, a ratio of left-over-right thickness was reported to account for breed and size differences. No significant difference was noted in resting laryngeal Grade 1 (0.99 ± 0.14; P < .0001) and in horses with exercising laryngeal Grade A abduction during exercise, 0.98 ± 0.12; P < .0001).132 However, horses with exercising Grade B and C had significantly lower ratio (0.81 ± 0.13) and (0.71 ± 0.14), respectively.132 Therefore, an atrophy of approximately 20% of the mid-body of the CAD muscle is sufficient to result in vocal and arytenoid collapse. When using the TEU on the caudal aspect of the CAD (i.e., the lateral compartment), a ~10% atrophy is associated with some degree of laryngeal collapse. Cornell is using TEU as a diagnostic test to help decide which patients with laryngeal Grade I or II or III and with some degree of laryngeal collapse should be treated with laryngoplasty vs ventriculocordectomy alone.

CT
As described above, CT is quite useful in assessment of the volume of the CAD muscle and has been described above.131 The incursion of the paranasal sinus into the airways is best defined and characterized by CT exam.110,133 CT image acquisition can be performed with the horse standing or under general anesthesia.

Temporohyoid osteoarthopathy is a predominantly degenerative process of the temporohyoid articulation leading to osseous enlargement and eventual fusion/ankyloses of the temporohyoid articulation.32,134,135 This enlargement leads to compression of the vestibulocochlear and facial nerves and under some stress fractures of the petrous temporal bone.32,135–137 It was originally believed to be secondary to otitis media/interna,135,137 but is now
predominantly associated with a degenerative process.\textsuperscript{138, 139} The purpose of the CT exam is to confirm disease of the temporohyoid articulation, and determine whether there is fusion of the temporohyoid articulation that poses a risk of petrous temporal bone fracture, which may be fatal.\textsuperscript{135, 140} The presence or absence of otitis can also be determined. From a surgical point of view, the CT exam confirmed whether the ankyloses is unilateral or bilateral, which would warrant consideration for bilateral surgery. Finally, it guides the surgery by characterizing the extent of the enlargement,\textsuperscript{138, 140} presence or absence of fracture in the squamous part of the temporal bone (which would emphasize delicate surgical manipulation), and defines the articulation of the stylohyoid and the ceratohyoid bone, which guides the surgical disarticulation.

Magnetic Resonance Imaging

The normal anatomy of the equine head has also been defined using MRI. Therefore, incursion of paranasal, dental, and para-airway structures into the upper airway can be established most accurately on MRI.\textsuperscript{141} Kaminsky et al, 2016 recently compared the value of CT imaging to 3.0T MRI imaging of the nasal cavity and the paranasal sinus.\textsuperscript{142} As expected, CT exam gave a better definition of the cortical bone whereas MRI gave better characterization of the soft tissue.\textsuperscript{142} When deciding which modality to use, the clinician should consider the target type of tissue to image, the longer acquisition time of the MRI, and the need for general anesthesia.

There is much less information on the value of MRI for assessment of the equine larynx. Garrett et al, 2009 reported on the ability to really define the laryngeal cartilage abnormality in horses with fourth branchial arch defect.\textsuperscript{143} They were able to show the multiple abnormalities seen with this disease which has an important effect on the potential treatment. Indeed, abnormalities of the thyroid lamina, and lack of cricothyroid articulation, and abnormalities to the muscles of the cranial esophageal sphincter were known, but the extent of the deviation of the cricoid cartilage has a critical effect on the potential surgical options. An important finding that was also seen on ultrasound exam in this study was that the CAL muscle seems to be normal.

High-Definition Robotic CT Systems

An emerging diagnostic modality that offers great promise in standing imaging of the structures of the equine upper airways is high-definition robotic CT systems. It is claimed to allow sub-millimeter-resolution images allowing 3-D volumetric imaging. The author will share experiences with this modality at the following link http://equine4ddi.com/ (Fig. 11).

3. DDSP

Etiopathogenesis

There are multiple etiopathogeneses to this condition. The evidence-based data listed below are reproducible models of this disease:

1. Desensitization of the pharyngeal branch of the vagus\textsuperscript{25, 144}
2. Bilateral resection of the thyrohyoideus muscle\textsuperscript{145}

Fig. 11. Robotic acquisition of a 6-year-old Quarter Horse head region for assessment of THO.
3. Bilateral desensitization of the hypoglossal nerves at the level of the ceratohyoid bone.

The first model introduced by Holcombe et al, 1999 hypothesized that DDSP was secondary to a dysfunction of the palatinus and palatopharyngeus muscle. The model did reproduce DDSP at rest and during exercise and therefore was a more severe form of palate displacement than most naturally occurring cases. However, this model also resulted in dysphagia, which is not a feature of iDDSP. In this model the cause of DDSP is a neuromuscular dysfunction of the nasopharynx. In a follow-up study, glossopharyngeal and hypoglossal desensitization at the level of the guttural pouch did not result in DDSP.

The next two models were able to recreate iDDSP and only during exercise. These latter two models of DDSP suggested that factors other than the intrinsic neuromuscular structures of the nasopharynx were implicated in iDDSP namely the thyrohyoid muscle and/or one or more of the following muscles: genioglossus, styloglossus, geniohyoides, and hyoglossus. More recent observations supported that early muscle fatigue may be at the root cause of some iDDSP. The current working hypothesis is that cervical descent of the larynx is the underlying cause of iDDSP. Strap muscle resection and laryngeal tie-forward seems to be effective in preventing caudal descent of the larynx.

The non-evidence-based data are centered on observation of intermittent or persistent DDSP associated with structural abnormalities surrounding the soft palate and/or epiglottic areas: palatal cysts, sub-epiglottic masses, granuloma, and epiglottic chondritis. These structural abnormalities as a cause for DDSP are anecdotal, yet frequently observed. However, the mechanism by which they are associated with displacement was thought to be structural: interfering with laryngopalatal seals. The author has observed recently that sensory input may play a role because blocking the sensory afferent results in near-immediate resolution of the palate displacement on endoscopy.

In summary, at the level of the nasopharynx, neuromuscular deficits, sensory abnormalities, and structures that interfere with the laryngopalatal seal represent the intrinsic pathway to DDSP. Extrinsic pathway seems to be tied to early fatigue of the external musculature that controls the position of the larynx.

Specific Diagnosis

Physiologically, we know that DDSP results in a marked airway obstruction during exhalation. Therefore, in horses working at high velocity, performance impairment occurs quickly after the occurrence of palate displacement which is referred to as “choking down” or “hitting a wall” by trainers and/or riders. Although 20–30% of horses with DDSP make no abnormal upper respiratory sounds (i.e., silent displacers) as described earlier, the majority have abnormal sounds. Historical reports of a “gurgling noise” are not pathognomonic of iDDSP but are a useful clue as to the potential differential diagnosis. Additional history to inquire about is whether billowing of cheeks has been observed. This observation is because the soft palate is displaced dorsal to the epiglottic cartilage airflow, during exhalation, is diverted through the mouth causing fluttering of the cheeks. This is rarely part of the history volunteered by the trainers/riders so should be inquired about from them.

Although dynamic endoscopic exam is the most helpful diagnostic aid, an external physical exam should focus on ruling out other causes of airway obstruction and the presence of infection of the upper airways, which could affect the neuromuscular control of the nasopharynx as introduced by Holcombe et al, 1998. In parallel, the observation of the presence and nature of nasal discharge and size of intermandibular lymph nodes should be determined; significant inflammation of the upper airway would dictate guttural pouch endoscopy. External symmetry of the nasal cavity and sinuses would help identify or suspect obstruction of the nasal passage.

In practice, most equine practitioners are asked to diagnose DDSP without the availability of OGE or HSTE. In those cases, the diagnosis must be based on the history and a resting exam, preferably immediately after exercise. This is far less accurate and associated with a significant high level of false-positive or -negative diagnosis. The focus of the exam with the horse standing is to identify intrinsic signs of nasopharyngeal abnormalities. Loosely “non-evidence-based” indicators are listed below:

- There is a significant association in epiglottic cartilage changes and the occurrence of DDSP. Look for appearance of epiglottis Grade II (thinner than the typical structure, of adequate length, and mildly flaccid with curled edges and no obvious vasculature on the dorsal aspect) or more marked flaccidity and loss of concavity of the caudal half of the soft palate
- An endoscopic evaluation of the guttural pouch is indicated if significant upper airway inflammation/infection is present especially if dysphagia is present. Look for enlarged lymph nodes near the pharyngeal branch of the vagus
- If the horse is still displaced while hyperneic, the cheeks billowing as air exits the oral cavity should be observed and a gurgling or snoring sound may be heard. If these signs are observed during examination, an immediate endoscopic exam should be performed to the epiglottic cartilage
- Presence of bruising on the dorsal aspect of the nasopharynx
If not displaced at the time of exam, introducing the endoscope in the proximal aspect of the trachea and retracting it induces displacement (both in normal or horses with naturally occurring DDSP). This allows one to look for any signs of ulceration or redness on the caudal edge of the soft palate.

One should also judge whether the horse seems to realize that it has displaced (makes an effort to replace its soft palate) and whether more than two swallows is needed to correct the displacement.

The presence or absence of subepiglottic masses/cysts or palatal cysts must also be ascertained.

The subepiglottic region should be observed; this may necessitate the use of laryngeal forceps to elevate the epiglottic cartilage.

DDSP may be caused by or associated with ary-epiglottic entrapment. Therefore, this abnormality must be ruled in or out. This might necessitate oral endoscopy (standing or under general anesthesia).

DDSP may be caused by tracheal aspiration (i.e., secondary to laryngoplasty). Here the treatment is to reverse the aspiration and not seek specific DDSP treatment.

Oral examination could be needed to identify palatal cysts, ari-epiglottic (AE) entrapment.

How Accurate Is Diagnosis Performed at Rest?

Eighty percent of horses with intermittent DDSP on treadmill do not have abnormality on resting endoscopy. This is because DDSP is a dynamic condition that occurs during exercise. Furthermore, the use of a characteristic history and findings of resting endoscopy alone resulted in a 35% misdiagnosis rate compared with diagnosis obtained from treadmill endoscopy.

Imaging

Although DDSP can be observed by radiography, this procedure is of limited value at this time. If air is present in the mouth, the thickness of the soft palate can be seen and it can be helpful in identifying palatal and subepiglottic cysts. Air in the oropharynx is considered abnormal by the author. There is some evidence that position of the larynx and hyoid apparatus might be related to the occurrence of DDSP and therefore assessment of these structures might become useful in the future through radiography. Currently, detecting a more ventral position of the basihyoid bone on ultrasonography has a low positive predictive value (36%) of DDSP during exercise. However, it has a high negative predictive value (89%). This test is not ready for clinical application yet given that the differences in position of the basihyoid bone is ~3 mm and this is clearly affected by the pressure on the ultrasound probe. Its value is more in research application on the position of the larynx and hyoid apparatus on the pathophysiology of iDDSP.

Exercise Examination

Dynamic endoscopy by OGE or HSTE is the gold standard. Sound analysis is no longer of much clinical importance now that the availability of OGE has proliferated throughout the world. The diagnosis of DDSP is obvious when we observe the soft palate positioned dorsal to the epiglottic cartilage for eight or more breaths during strenuous exercise. However, horses with exercise-induced DDSP do not necessarily displace during every exercise test nor at every race. The DDSP diagnosis rate is lower with OGE exam if the exercise intensity is not as strenuous as treadmill testing, probably because protocols are less well established. These data are improving as the need for maximal speed is emphasized during overground exam. This means that a negative diagnosis of DDSP during videoendoscopy during exercise may not rule out this diagnosis. Therefore, during high-intensity exercise, we should recognize prodromal signs of DDSP. Those that are indicative of palatal instability are billowing of the soft palate (evidence of palatal instability), appearance of flaccidity of the epiglottic cartilage, and retraction of the larynx.

4. Treatment

Management After Initial Diagnosis

Allen et al, 2011 reported on the first systemic review of the numerous treatments of iDDSP. Because of the heterogeneity of the prior published papers on the various treatments, the lack of appropriate controls (including the status of disease in control), they were not able to determine which procedure is the most appropriate in management of this condition.

There are published reports that suggest that nonsurgical treatments (rest and the use of tongue-tie) of this condition are associated with a success rate comparable to surgery (in general, not all procedures evaluated) and therefore medical treatment should be considered seriously. Only two papers have looked at the effect of the tongue-tie on upper airway mechanics in horses during exercise. One study was performed in normal horses while the other was in normal horses after having performed a strap muscle resection. It was shown that it had no negative or positive effect during exercise. With the goal to enhance the effectiveness of the tongue-tie, various bits have been proposed namely the “w” bit and the Serena Song bit. Consistent with the principle of the laryngeal tie-forward surgery, an external device (see Conflict of Interest Disclosure) that places the larynx forward and dorsally effectively controls DDSP in experimentally-induced DDSP.

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Other changes in tack of horses are commonly described in the management of palatal instability or iDDSP, usually with other changes (rest or increase training to improve fitness). The use of the figure-eight nose band or dropped noseband is claimed to be effective in preventing air into the oropharynx and it is logical that this would predispose the soft palate to instability if the air is maintained at that location. There are no data to demonstrate whether this happens and why air would remain there after a swallow which is reasonably frequent during exercise. Other anecdotal tack changes suggested for managing DDSP are those that decrease head flexion. A bitless bridle has been suggested for sport horses.

Horses with pharyngeal inflammation have been recommended to be treated first with systemic, and perhaps topical, anti-inflammatory agents unless a prior equine protozoal myeloencephalitis (EPM) diagnosis has been made. There is a significant relationship between the occurrences of DDSP and pharyngitis. Holcombe et al, 1999 has shown that damage of the pharyngeal branch of the vagus nerve as it traverses the medial wall of the gulletural pouch can result in DDSP; inflammation is thought to be the most common cause of this pharyngeal nerve dysfunction. Two different anti-inflammatory protocols that are used as treatment are below:

1. Dexamethasone (25–30 mg by mouth [PO] or IV SID for 3 days, 20 mg PO or IV SID for 3 days, 10 mg PO or IV SID for 3 days, and 10 mg PO or IV EOD for three treatments), and
2. Prednisolone (300 mg PO twice a day [BID] for 2 weeks, 300 mg PO SID for 2 weeks, and 300 mg PO EOD for 2 weeks). The dexamethasone protocol is more potent

Anecdotally, structural abnormalities of the larynx and nasopharynx such as sub-epiglottic cyst, sub-epiglottic granuloma and ulcers, palatal cyst, and epiglottitis disturbed the laryngopalatal seal and predisposes horses to DDSP. When present, the treatment should target those lesions. Cysts, which are mainly congenital malformations, should be excised using a laryngotomy or endoscopic laser. Chronic inflammatory disease, such as granulomas and epiglottitis are more difficult to address. However, if there is not a prolonged history of medical treatment, the latter should be performed first. The standard treatment for horses with acute or sub-acute epiglottitis is 10–21 days of antimicrobials (usually trimethoprim-sulfadiazine, 15 mg/kg PO, BID or enrofloxacin 7.5 mg/kg PO SID) and nonsteroidal anti-inflammatory medications (phenylbutazone, 2.2 mg/kg PO, BID for 5–7 days, then SID for 3–5 days). Although controversial, topical nasopharyngeal anti-inflammatory preparations are frequently used in the author’s practice. The preparation we use is a throat spray at 20 cc BID (made up of 250 mL glycerin, 250 mL dimethyl sulfoxide (DMSO) 90%, 500 mL nitrofurazone, and 50 mL of dexamethasone [2 mg/mL]), or a steroid inhaler (beclomethasone) has been used by others.

Two-year-old horses with DDSP may have an “immature nasopharynx,” so owners should consider waiting a year before pursuing any surgical treatment. Finally, an unfit horse’s fitness level should be raised before considering any surgical treatment.

Surgical Treatment

There are many surgical treatments for this condition whose etiopathogenesis is clearly not fully understood and/or has different pathogenesis. With the absence of a valid meta-analysis to identify the best treatment, the following represent the approach used by the author. Horses diagnosed with iDDSP after two or more races in which the medical/tack modification has failed to correct the problem, are candidates for surgical treatment. In sport horses, DDSP is far less common, the outcome more subjective, and surgical results reported less often.

Quinlan introduced and popularized the first surgical treatment staphylectomy. This treatment is still used (but not recommended by the author for iDDSP) as part of a composite treatment in general in association with strap muscles resection. Aside from the staphylectomy, there are three categories of surgical treatments:

1. Those that target correcting the intrinsic nasopharyngeal structures (cyst/granuloma removal)
2. Those that seek to increase palatal stiffness (by thermal palatoplasty by cautery, or laser, chemical palatoplasty by injection of sclerosing agents, and tension palatoplasty by suturing)
3. Those targeting the position of the larynx and hyoid bone, such as strap muscle resection and laryngeal tie-forward

The primary benefit of other surgery of the intrinsic structure of the nasopharynx relevant to the soft palate is related to removal of granulomas, cysts, and abnormal subepiglottic tissue. One should be aware that the subepiglottic tissue is quite sensitive to surgical trauma (laser, blade, or scissors), and so the veterinary surgeon should be cautious about these areas, especially during repeated surgery. Staphylectomy is currently only performed for occasional resection of soft palate cysts, rarely for soft palate ulcer, or as a part of a composite treatment for persistent DDSP after a laryngeal tie-forward has been performed.

The rationale for targeting a procedure that increases palatal stiffness is being questioned given the results in three studies. In one study using injection of a sclerosing agent in the soft palate, the authors did not find evidence of sustained change in stiffness or morphology of the soft palate at up to 6
In another study, some histological evidence of fibrosis (168 days post injection) was seen which might increase rigidity. In the third study, fibrosis was also induced with a diode laser (15 watts; 1 s on, 1 s off) but the biomechanical property was not changed at 45 days. Therefore, although we can induce some fibrosis of the soft palate, its biomechanical value may be limited if at all present. Furthermore, there is a chance that inducing fibrosis would also damage the palatines muscle or interfere with its function and for those reasons, these treatments are no longer very popular. The author’s view on this surgical goal is that if increasing stiffness of the soft palate could be performed reliably and for a prolonged period of time, it would likely reduce the fluttering of the caudal free edge of the soft palate and thus reduce abnormal upper respiratory noise associated with this flutters. Whether it would reduce the airway obstruction is far less likely.

Strap muscle resections (bilateral partial stenothyroidectomy) with a reported success rate of 58–70% remains one of the most popular treatments of this condition. With the horse in dorsal recumbency under short-acting or other form of general anesthesia, a skin incision (5–7 cm in length) is made centered on the ventral aspect of the cricoid cartilage on the midline. After incising the subcutaneous tissue, the sternohyoideus muscles are divided using curved scissors. With finger dissection on the lateral aspect of the cricoid cartilage, the left and right sternohyoideus muscle is identified caudal to its tendinous insertion on the lamina of the thyroidea cartilage. The tendon is transected 1–2 cm caudal to thyroid cartilage to avoid trauma to the cricothyroid muscle which tenses the vocal cord or caudal laryngeal artery. A 3-cm section of each sternothyroideus muscle/tendon is then removed. This prevents re-attachment of the cut end of the muscle on the cricoid or thyroid cartilage (Fig. 12).

Laryngeal tie-forward procedure is also performed with the horse under general anesthesia in dorsal recumbency. As part of this procedure, the partial stenothyroidectomy is performed as described above and the larynx is elevated dorsally and rostrally using sutures placed from the thyroid cartilage to the basihyoid bone. Because the weak part of this procedure is anchoring the sutures to the thyroid cartilage, a couple of modifications have been described:

1. Four passes of sutures in the thyroid cartilage (Fig. 12)
2. The use of surgical buttons to buttress the thyroid cartilage. In addition, various sutures pattern around the basihyoid bone have been described. Mechanically, the procedure results in rostral and dorsal movement of the larynx and caudal and dorsal elevation of the basihyoid bone.

There is far less information on the treatment of horses with persistent DDSP. No evidence-based study is present here to guide the clinicians as to how to manage these cases. In our experience, if there is any tracheal aspiration of feed material, this should be resolved first. Any painful condition that has epiglottic ulceration or chondritis must also be resolved. Then the surgical steps in the order suggested by Ortved et al, 2010 should be used. Redundant ati-epiglottic tissue is first removed, followed by a laryngeal tie-forward and, if needed, laser staphylectomy is performed.

Nasopharyngal Collapse

**Etiopathogenesis**

The etiology of nasopharynx collapse (NPC) is largely unknown. Males are more affected than females. It should be pointed out that some nasopharyngeal collapse can have a different degree of severity (only roof, unstable palate, entire nasopharynx) and can also be associated with dysphagia. Immaturity and systemic disease such as hyperkalemic periodic paralysis (HYPP) and vitamin E and selenium deficiency have been reported to affect the neuromuscular control and function of the upper airway and can be associated with dysphagia (predominantly Vitamin E, SE deficiency). Most commonly, nasopharyngeal collapse is presented as a source of upper airway noise and is discovered during dynamic endoscopy during exercise. We do know that the stylopharyngeus muscle is the main dilator of the roof of the nasopharynx. This muscle is activated during inhalation and has tonic activity that increases with an increase in exercise intensity. Experimental data from Michigan State showed that collapse of the roof of the nasopharynx can be reproduced by desensitization.
of the glossohyaryngeal nerves at the level of the
guttural pouches. Therefore, upper airway inflam-
mation of those efferent nerves to the dilators of the
nasopharynx can result in NPC and thereby the
rational of using anti-inflammatory medications in
the management of this condition.

It is also known that the vertical diameter of the
nasopharynx is affected by neck position,100 This is
believed to be a geometrical consequence of bending
of the upper respiratory tract, which increases resis-
tance.14,100 In addition, Cehak et al, 2010 reported
that not only was the diameter reduced with head
flexion but also the shape of the nasopharynx
changes from round to oval, suggesting that it in-
creases the compliance of its wall.100 Mechanical
devices that change the head position during exer-
cise could then be logical to manage this condition.

Another hypothesis is that some horses with dor-
sal collapse of the nasopharynx have sub-clinical
guttural pouch tympany and therefore may be im-
proved with surgical treatment of this condition.28

Certainly, unilateral collapse of the roof of the na-
sohyarynx is a strong indication of guttural pouch
disease and the need for endoscopy of those struc-
tures. Usually unilateral collapse of the roof of the
nasopharynx is associated with guttural pouch em-
pyema. Bilateral sub-clinical guttural pouch tym-
pamy was introduced as either being a congenital or
an acquired stricture or stenosis of the “valve” of the
guttural pouch.28 This would prevent rapid equil-
ibration of the guttural pouch pressure with the
nasopharyngeal pressures.

Inspiratory pressure is thought to activate the
driving receptors for the increase in muscular ac-
tivity during exercise. The afferent loop to these
pressure receptors may therefore also be part of
the clinical disease in horses where recruitment of
the nasopharyngeal dilators is dysfunctional. Indeed, in “normal” experimental horses, desen-
tization of the nasopharynx with local anesthesia
results in nasopharyngeal collapse.189 It is felt
that the upper respiratory sensory receptors are
located in a submucosal area and receive afferent
innervation from the internal branch of the cra-
nial laryngeal, or the vagus, or the trigeminal
nerves depending on where they are located in the
upper airways.25,190–192 Therefore, inflamma-
tory condition of the upper airway may interfere
with either or both the sensory or motor innerva-
tion to the upper airways,188,189 and would be the
justification for the anti-inflammatory treatments in
the management of this condition. Older horses with NPC have been reported to have a
poor prognosis.193 Perhaps this is because the
inflammatory cause of NPC would be less frequent
in older horses and more significant structural
damage would be present.

Unilateral nasopharyngeal collapse is, in the au-
thor’s experience, a fixed obstruction associated with
stylohyoid bone fracture and or infection.31,134,140,194
The cause of these fractures is largely unknown.

We have observed some fracture associated with
“palatal injection.” These “palatal injections” are
relatively frequent in Standardbred racehorses and
are really “paralaryngeal injections” that do not re-
ally reach the soft palate. The injections can, how-
ever, reach an area between the thyrohyoid bone
and the stylohyoid bone and lead to infection. In-
fecion at that area could result in local oropharyn-
geal or nasopharyngeal swelling depending on its
location. This has resulted in some horses as a
large (i.e., egg size) bulge compressing the ipsilat-
eral lateral wall of the nasopharynx. Fracture of the
stylohyoid or ceratohyoid bone is associated with
a similar swelling but is distinguished by the detec-
tion of submucosal hemorrhage at the apex of the
swelling on endoscopy. Fractures of the stylohyoid
and ceratohyoid bones are rare. They have been
associated with THO.31,134,140 The author believes
that the laryngeal tie-forward procedure may pre-
dispose a very small number of horses to stylohyoid
bone fracture.

Bilateral nasopharyngeal wall collapse causes an
abnormal upper respiratory noise and airway ob-
bstruction during exercise. It more commonly pres-
ents as an entire lateral wall collapse and is a very
debilitating disease in terms of severity of the air-
way obstruction. This is likely a result of afferent
or efferent neuromuscular dysfunction as described
above. However, in three racehorses, it was sec-
ondary to a marked increase in nasal resistance.
A second form of bilateral dynamic lateral wall col-
lapse usually presents as a horse with an abnormal
upper airway noise with a very questionable airway
obstruction. On endoscopy, a longitudinal leading
data of the nasopharynx at the level of the area
immediately dorsal to the lateral wall attachment of
the soft palate collapse toward the midline. The
cause of this obstruction is unknown.

Management
In neonatal foals, nasopharyngeal collapse and dys-
phagia is often, (but not always), transient within a
few weeks, and treatments usually consist of feeding
from a pan and supportive medical therapy tailored
to the foal’s need (antibiotics, IV fluids, etc.).57

To manage horses where the cause or the exacer-
bate of the NPC is due to head flexion, which
contributes to a decreased dorsoventral diameter of
the nasopharynx, a change in tack should be consid-
ered. The change in head flexion must of course be
consistent with the required horse’s head position
during working activity. For example, the “rollkur”
is a training method used in dressage competition
that may or may not be reduced. The effect of head
position on dorsal nasopharyngeal diameter is con-
sistent with the prevalence of nasopharyngeal insta-
Bil
ility and collapse seen in sport horses during
exercise where head flexion is much greater than
racehorses.13,14 This is a key reason where OGE is
preferable to HSTE in sport.
In terms of medical management, if upper airway inflammation is present that is significant enough to affect the afferent or efferent neural innervation, anti-inflammatory treatment protocols are logical. It should be emphasized that there are no double blind or even case-control data available to guide the clinician. We have used empirically one of three anti-inflammatory protocols:

1. Dexamethasone (30 mg PO or IV SID for 3 days, 20 mg PO or IV SID for 3 days, 10 mg PO or IV SID for 3 days, and 10 mg PO or IV EOD for three treatments)
2. Prednisolone (300 mg PO BID for 2 weeks, 300 mg PO SID for 2 weeks, and 300 mg PO EOD for 2 weeks; Note the dexamethasone protocol is more potent)
3. Inhalant puffers such as fluticasone 250 microgram (Flovent): 4–5 puffs of the metered dose inhaler BID for 10 days then SID or EOD for 3 weeks depending on severity. (Note that only the puffer in the metered dose inhaler is suitable; not the powder disk inhaler)

Horses that are HYPP positive should respond to acetazolamide therapy. No case control data are available to guide the prognosis.

Horses with dorsal nasopharyngeal collapse may respond to fenestration of the guttural pouches or removal of plica salpingopharyngeal membrane. Alternatively, midline laser-assisted nasopharyngeal fenestration (a technique introduced by Woodie, Rood and Riddle, KY) may be considered and is the author’s preference because it is simple and does not offer the possibility of fibrosis and stenosis of the guttural pouch opening or the early course of the auditory tube.

In horses with severe nasopharyngeal collapse, usually accompanied with iDDSP, many have been treated with laryngeal tie-forward and alar fold resection. This is an empirical treatment and has not been objectively evaluated through a case-control analysis. In addition, the author has treated three severely affected Thoroughbred racehorses in which we diagnosed an abnormally high nasal resistance. The treatment consisted of standing nasal septum resection and bilateral alar fold resection using a modification of previously described techniques under general anesthesia. Two horses received an additional laryngeal tie-forward. All three returned to racing and two won their first start although none of them were high-level racehorses.

Laryngeal Collapse

There are multiple forms of laryngeal collapse and clinicians should be aware that although RLN is the most common cause, it is not the only cause of collapse of the hemilarynx. Bilateral collapse of the arytenoid cartilages should be suggestive of systemic disease (e.g., liver disease, lead poisoning).

Recurrent Laryngeal Neuropathy

Etiopathogenesis

Recurrent laryngeal neuropathy (RLN; which used to be called laryngeal paralysis or idiopathic laryngeal hemiplegia/hemiparesis) is the most common cause of left laryngeal collapse during exercise and is associated with decreased or absent abduction of the left arytenoid at rest. The disease is characterized histologically (predominantly on the left side) as a progressive loss of myelinated fibers, axonal loss, and with regenerating axons in the distal aspect of the recurrent laryngeal nerve. The primary lesion seems to be axonal in nature with secondary myelin loss although the reverse may be true. The lesions to a much milder degree are also seen in the right side. At this time RLN in horses is classified as a distal axonopathy and is a bilateral mononeuropathy limited to the recurrent laryngeal nerves.

The cause of the disease is largely unknown. Association with a horse’s height (withers height) and a genetic basis on increased prevalence of the disease have been numerous. Gradual nerve elongation has been associated with ischemic damage to the nerve. Trying to tease the purely height effect from a separate yet associated genetic effect in the prevalence of RLN has been investigated by case-based epidemiological studies and by genomic-wide association. Poncet al, 1989 reported on the 59 “related” offsprings of a French riding stallion confirmed to have RLN by postmortem exam. The offspring had a prevalence of nearly 50% RLN compared with 10% in the 50 controls with the status of disease and control all determined by resting endoscopy. The affected horses were taller than unaffected horses as was reported by others. The heritability of RLN in horses in similar studies has been estimated ranging from 0.2 to 0.6.

Dupuis et al, 2011 identified two genome-wide loci in warmbloods on chromosome 21 and 31 but was a protective halotype in controls. In a population of Thoroughbreds, Boyko et al, 2014 did a genome-wide association study GWAS in 282 RLN-positive vs 268 RLN-negative horses using the resting endoscopy phenotype. They found a strong genetic correlation between the withers height and RLN (LCORL/NCAPG locus on ECA3). The relationship between LCORL/NCAPG region and withers heights had been previously identified. If there is not a modifier loci altering the prevalence of RLN, the studies to date suggest that it may be difficult by breeding restriction to restrict the prevalence of RLN without reducing the height of unaffected horses. Another concern is that according to some authors’ histopathological analysis, all Thoroughbreds are affected with at least subclinical RLN, which make the phenotype based on endoscopy less strong.

Inhalant puffers such as fluticasone 250 microgram (Flovent): 4–5 puffs of the metered dose inhaler BID for 10 days then SID or EOD for 3 weeks depending on severity. (Note that only the puffer in the metered dose inhaler is suitable; not the powder disk inhaler)
Aside for idiopathic (but likely heritable) naturally occurring RLN, any trauma or diseases affecting the vagus or the recurrent laryngeal nerve can result in the same condition. Indeed, perivascular injection, esophageal surgery, guttural pouch mycosis,27,216 and planned surgical transection of the recurrent laryngeal nerve 217 can all result in RLN. Cervical trauma to the recurrent laryngeal nerve and/or vagus is often associated with sympathetic nerve damage because of the close approximation of the sympathetic trunk to those structures. Signs of Horner’s syndrome may be helpful in identifying the cause of RLN in a given horse.

In summary, naturally occurring or traumatic or inflammatory RLN can result in resting endoscopic ipsilateral arytenoid cartilage movement asymmetry and asynchrony as well as various degrees of arytenoid cartilage and vocal cord collapse during exercise.

Diagnosis
The various clinical (abnormal upper respiratory noise and/or poor performance), endoscopic (generally left vocal cord/arytenoid failure of full abduction or collapse as seen in Table 1) have been described earlier. The flow dynamic consequence of a decreased cross-sectional area of the left hemilarynx and a change in pressure profile in the nasopharynx lead to predisposition for right vocal cord and right ary-epiglottic fold collapse, which is often seen during dynamic endoscopy.9 Red-flag endoscopic features that may suggest to the clinician another cause of the laryngeal collapse are listed below:

1. Bilateral arytenoid and/or vocal cord collapse (Fig. 13B)85,215,218

2. Enlargement of one or more of the arytenoid cartilage68,118,219,220

3. Subluxation or medial deviation of one or both medial aspects of the corniculate processes (Fig. 13A and C) with or without medial folding of the lateral borders of the epiglottic cartilage98,221

The hallmark of RLN is various degrees of ipsilateral atrophy of intrinsic laryngeal muscle fibers that result in a change in muscle volume. This change in CAD volume may be detectable on digital palpation of the larynx, and quantified using esophageal ultrasound or CT exam. This atrophy of the muscle fiber results in increased echogenicity of CAL and CAD detectable on laryngeal ultrasound. These muscle changes are the basis of imaging-diagnosis modalities to identify RLN.

To further determine the level of neuropathy, various neurodiagnostic tests have been used in the past targeting determination of nerve conduction.223,224 The thoraco-laryngeal reflex (i.e., slap test)225 response was introduced by Cook and Thalhammer, 1992 as a possible test to identify slower nerve conduction in horses with RLN.226 This test as described does not measure true nerve conduction but rather latency, which may be affected by many factors, so it is not a simple and reliable test.224 This test is not recommended as a diagnostic or research tool. True measurement of recurrent laryngeal nerve conduction has been reported227 and may become an accurate and practical test in the future although it is a primary research tool at this time.
Treatments

**Ventriculocordectomy and Ventriculectomy**

This technique was introduced by Williams in 1902 and modified and popularized by Sir Frederick Hobday. Many studies from the Michigan State University in horses with experimentally created Grade IV laryngeal hemiplegia have led to the following conclusions:

1. There are no mechanical advantages in terms of airway patency to perform a ventriculectomy.
2. Ventriculocordectomy (VC) improves airway mechanics although more so with bilateral procedures.
3. Both ventriculectomy and ventriculocordectomy reduce abnormal upper respiratory noise, but ventriculocordectomy is more effective.

These results in an experimental population are broadly supported in naturally occurring disease.

In a clinical population unilateral or bilateral laser-assisted VC or ipsilateral VC and right ventriculectomy are the preferred treatment for use in sport and draft horses where abnormal respiratory noise is the main complaint. Ventriculectomy and/or ventriculo-cordectomy techniques are commonly combined with laryngoplasty.

**Laryngoplasty**

Since the introduction of laryngoplasty by Marks in 1970, multiple modifications of the techniques have been introduced, probably with incremental improvement in success rates using historical controls only. What are the evidence-based data?

We know that the target abduction is somewhere around 88% to improve respiratory mechanics within 4% of normal. In experimentally created laryngeal hemiplegia in horses, treatment by laryngoplasty has led to the following conclusions:

1. Laryngoplasty restores airway mechanics to normal. This statement has been challenged, also in experimentally created RLN, and although respiratory mechanics have been mainly restored, ventilation was not. Given the results in clinical treatment of naturally occurring RLN, it is unlikely that this procedure restores airway mechanics to normal. Furthermore it is associated with complications such as prosthesis failure, chondritis, exercise-induced pulmonary hemorrhage (EIPH), esophageal reflux, and DDSP.
2. Laryngoplasty alone reduced abnormal upper respiratory noise but not as effectively as bilateral ventriculocordectomy. In a clinical population, it is very rare that a laryngoplasty is performed without a ventriculectomy or ventriculocordectomy. And it has been shown that horses which had a laryngoplasty without a ventriculectomy have been reported to be five time more likely to have an abnormal upper respiratory noise, thus supporting the findings in experimental horses.

3. There are no added benefits in terms of airway patency of performing ventriculocordectomy unilaterally or bilaterally after a laryngoplasty has been performed. The results in clinical populations do not strongly support this latter experimental conclusion. Very few, if any, surgeons will perform a laryngoplasty without a ventriculectomy or ventriculocordectomy. It is likely that this conclusion in the experimental animal was based on the suboptimal degree of precision measured by respiratory mechanics. Indeed, if the laryngoplasty truly restores the airway to normal, how can the addition of ventriculocordectomy make it “more normal?”

Nevertheless, laryngoplasty is the current gold standard of treatment of horses with unilateral arytenoid and vocal cord collapse associated with RLN. Important recent elements of this treatment that the author considers noteworthy are below:

1. The Dixon laryngeal Grade 1–5 (Table 2) is used in the clinical population to characterize the postoperative degree of abduction achieved.
2. The average location of the arytenoid cartilage within a few days of a tieback is a Grade II but is Grade III at 6 weeks postsurgery.
3. Most of the loss in abduction after surgery occurs in the first 6 weeks postoperatively and the correlation between first day scoping and 6 weeks or 33 months is poor but the correlation between 6 weeks and 33 months is good.
4. Facilitated ankyloses of the cricoarytenoid joint is helpful to maintain abduction.
5. Performing a ventriculocordectomy as the step immediately prior to laryngoplasty improves the degree of abduction obtained.
6. Soft palate displacement is frequently seen in horses after a laryngoplasty.
7. Standing laryngoplasty is the preferred method to perform this surgery because it allows more precise intraoperative positioning of the arytenoid cartilage.

**Partial Arytenoidectomy**

Arytenoidectomy is one of the oldest treatments of RLN and arytenoid chondritis. The procedure, first introduced as a treatment of roaring in horses, has evolved from the original description of a total resection of the arytenoid cartilage to a sub-total where the corniculate process and muscular process is left in place to a partial arytenoidectomy where only the muscular process is left in place. What is the best procedure in terms of restoring airway patency?
as determined by measurement of upper airway mechanics? This question may not be relevant in some cases, aside from cases affected with arytenoid chondritis when the location and extent of the disease process affecting the arytenoid cartilage influence the selection of procedure. In experimental animals, left laryngeal hemiplegia was created in unaffected horses and a sub-total arytenoidectomy was performed.252 No significant improvement in airway mechanics was reported indicating that this procedure is less likely to expose the horse to postoperative tracheal aspirations. On the contrary, the partial arytenoidectomy procedure has been shown, also in an experimental model of laryngeal hemiplegia, to improve airway mechanics in horses during exercise.67,69 This improvement was not as good as seen after laryngoplasty either using historical controls230,246 or within the same horse submitted to the two subsequent procedures.69

In a clinical population, partial arytenoidectomy was once thought of as a salvage procedure46,253 but is now recognized as an effective alternative to laryngoplasty.68,69,236,254 Recent clinical studies indicate that in horses that have raced before, return to racing is approximately 80%, perhaps higher than after laryngoplasty, which is reported to be approximately 70%. Both partial arytenoidectomy and laryngoplasty procedures properly result in shorter racing careers when compared with peers,216,217 although that result has been challenged recently.255 The level of performance (using earning as a surrogate for airway patency) after partial arytenoidectomy seems to be inferior to that of racehorses with laryngoplasty,236 indicating the superiority of the latter procedure when successful (i.e., successful tieback is better than a successful partial arytenoidectomy).

In summary, the data suggest that laryngoplasty yields superior results in terms of improving airway patency, although results after a partial arytenoidectomy seem to be more uniform. The degree of restoration of airway patency is of course dependent on the demand of the desired athletic endeavor of a particular horse.

Laryngeal Reinnervation

Laryngeal reinnervation procedures (nerve-pedicle or nerve implantation) were first introduced in humans.256,257 At the time, the value of the reinnervation was to prevent atrophy and provide bulk to the reinnervated muscle. This is still considered of value in reinnervation of the vocal cord.258 The nerve-pedicle, nerve implantation procedures, as well as nerve anastomosis of the first or second cervical nerve to the recurrent laryngeal nerve were then adapted to experimental horses in 1989.259–261

In experimental horses, the value of the nerve-muscle pedicle transplant procedure was evaluated by Fulton et al, 1991.262,263 This group was able to show an improvement of the airway patency as assessed by determination in airway mechanics after transplantation of nerve-muscle pedicle(s) in the left CAD muscle of a recently denervated muscle. However, the time for this maximal effect (~52 weeks) remains the main negative of this procedure: the long delay associated with reinnervation.

The target clinical patient for a reinnervation is a clinically affected horse (often 1–2 years old) with laryngeal Grade II or III where the muscle volume of the CAD is still significant. Is there a need for transection of the native recurrent laryngeal nerve to avoid the blocking effect of dual innervation? These horses still have significant arytenoid movement and transecting the native recurrent laryngeal nerve would worsen the laryngeal collapse until reinnervation occurs. Other questions not answered by the study in experimental animal were: What are the results in horses with naturally-occurring disease? Is there a way to speed up the reinnervation process? Here we are missing a double blind study, yet much progress has been made in answering this question in great part by the work of Ian Fulton and colleagues in Australia.264,265 In his population, his group has not transected the native recurrent laryngeal nerve and still reported success in terms of return to racing as similar to what is seen after laryngoplasty. The hypothesis is that the transplanted nerve-pedicle reinnervated the denervated muscle and muscle still innervated by native recurrent laryngeal nerve are excluded from this process. The reported successes confirm that the procedure is applicable in horses with naturally occurring RLN.

The main advantage of the laryngeal reinnervation technique is its lower morbidity once the horse has recovered from general anesthesia. This is because it provides a more physiological restoration of function without compromising airway protective mechanisms. The complication rate after laryngeal reinnervation is consequently very low.

How can reinnervation be improved? The author currently has abandoned the nerve-pedicle procedure in favor of a newer technique introduced in human laryngeal reinnervation described by the group led by J. P. Marie in Rouen, France.266 There is a question as to the quantity and extent of the reinnervation obtained from the first/second cervical nerve. As a result, the abduction of the arytenoid cartilage might not be sufficient after reinnervation to prevent vocal cord collapse during exercise. Therefore, unilateral ventriculocordectomy with reinnervation procedures was performed.

How can the speed of reinnervation be improved? Tessa Gordon and colleagues have shown that 1-hour electrical stimulation at the time of injury
can enhance the speed of motor neuron regeneration. This offers us the possibility of improving the speed of reinnervation after laryngeal reinnervation procedures in horses. At this time, the J.P. Marie technique in clinical patients is being used and the rehabilitation process of the CAD muscle enhanced by electrical stimulation investigated, which is described below.

Electrical Rehabilitation of the CAD Muscle

Reanimation of the human larynx has been investigated since the early 1990s. Ira Sanders and David Zealear were pioneers in this modality and many others followed their lead of electrical stimulation treatment of humans with unilateral or bilateral vocal cord paralysis, generally using the dog or cat as a model. The technique has been investigated in humans and although voice restoration is an important need in humans, airflow patency is also needed in many patients.

In horses, this is an emerging modality of reanimation thanks to a large collaboration with colleagues at Hackensack University Medical Center (Ira Sanders, Liancai Mu), Royal Veterinary College, University of London (Justin Perkins, Emil Olsen, and Richard Piercy), Perugia University (Marco Pepe and Marta Cercone), University of Guelph (Heather Chalmers, Aitor Gallastegui Menoyo and Laurent Viel), Maison-Alfort and Clinique Equine (Céline Mespoulhès-Riviere, Antoine Lechartier, Olivier Brandenberger, Amelie Vitte and Fabrice Rossignol) and Cornell University (Jon Cheatham, Marta Cercone). Since 2004 the group has investigated the use of functional electrical stimulation to modulate treatment of upper and lower airway diseases. Neuroanatomy and function of the relevant laryngeal muscles were mapped. In parallel studies, stimulation of the recurrent laryngeal nerve, CAD, and cricothyroid muscles in both native and/or denervated states were performed. To improve patient selection and track the rehabilitation of the CAD muscles, imaging modalities as they correlate with CAD muscles volume and immunohistochemistry were performed. Other groups or authors have also investigated electrical stimulation of the larynx.

Complications of Treatment

Tracheal Contamination

Both arytenoidectomy and laryngoplasty surgical procedures interfere with the airway’s normal protective mechanisms and have similar rates of airway contamination and coughing. On occasion, some horses suffer from an unacceptable amount of airway contamination after either laryngoplasty or partial arytenoidectomy. This is a well-recognized complication that has been reported for many years. This distressing complication can be a welfare issue in affected horses. The reported principles of treatment revolve generally around removing the laryngoplasty sutures and lysis of the adhesions surrounding the cricoarytenoid joint so that the arytenoid cartilage returns to a neutral position. The latter step is especially important if a facilitated ankyloses of the cricoarytenoid joint has been performed by one of the techniques described. Unfortunately, no evidence-based data exist to guide the proper management of this condition.

A review of the cases will be presented for management of various degrees of tracheal aspiration and palate displacement. It has been reported that DDSP is frequent after laryngoplasty and DDSP is also seen after partial arytenoidectomy. A common cause of DDSP after laryngoplasty is due to tracheal penetration of feed material through oropharynx contamination or esophageal reflux. This emphasized the need for a proper diagnostic investigation to understand the cause of the aspiration post laryngoplasty. This is reviewed under diagnostic methods for dysphagia and described above. In terms of treatment, strategic injection bulking is also used by the author.

Persistent Complaint of Upper Airway Obstruction/Abnormal Noise After Surgical Treatment

Persistent complaint of upper airway obstruction/abnormal noise may be due to failure of abduction or collapse of additional soft tissue. Collapse of the remaining parts of the vocal cord, of the contralateral vocal cord, of the contralateral aryepiglottic fold, DDSP can all contribute to persistent noise and/or poor performance after a laryngoplasty. Some of this associated tissue collapse is predictable based on flow studies given that laryngoplasty does not restore normal geometry to the larynx. Post-laryngoplasty DDSP is speculated by the author to be associated with the occurrence of tracheal penetration of feed material. Regardless, persistence of noise or airway obstruction after laryngoplasty requires at least a resting endoscopic exam. In addition, unless the abduction is a Dixon Grade V, a dynamic exam is preferred to identify all the components of the persistent upper airway noise and/or obstruction. The frequency of the aforementioned post-laryngoplasty soft tissue collapse argue for considerations to perform bilateral ven-
triculocordectomy and ary-epiglottic folds with a laryngoplasty procedure.

There was an association between laryngoplasty and the development of EIPH and airway inflammatory disease in a case-cohort study. Both of these support the documentation of shorter racing career reported in the past. It has been proposed that the interference with the native protective mechanism of the larynx by the laryngoplasty predispose to pulmonary inflammation and fibrosis of the pulmonary parenchyma. Both factors are likely to increase the occurrence and severity of EIPH.

Failure to Maintain Abduction

The loss of abduction in the first 6 weeks post laryngoplasty has been well described by the classical paper of Dixon et al, 2003. However, there is ample evidence that a Dixon laryngeal Grade III (modest abduction) is compatible with good athletic performance. Moderate abduction of the arytenoid 6 weeks after surgery is likely to be maintained and is sufficient for racing soundness (probably the hardest clinical test of this treatment) if the arytenoid is stable during exercise and no other soft tissue collapse is present.

This has led many investigations on various techniques to improve the stability of the upper airways. They can be classified under the following:

1. Increased stability of the cricoarytenoid articulation
2. Increasing stability of the suture-cartilage interaction
3. Better abduction intra-operatively

Laryngeal Collapse Without RLN

There are many laryngeal collapses that resemble RLN prompting our human counterparts to suggest the term “laryngeal movement disorder.” The affected horses have no evidence of RLN yet exhibit laryngeal collapse during exercise (Fig. 13, A–C). The horses in Figure 13 all had arytenoid collapse during exercise without evidence of RLN. No experimental or histopathological data was available to explain the collapse. The author hypothesized that in horses with the collapse represented in Figure 13A, the corniculate process medialize into the airway because of a structural weakness at the junction of the corniculate and body of the arytenoid cartilage. We have information of the elastic content of the body of the arytenoid cartilage and propose that a greater percentage of elastic content at the junction cause the body and corniculate cartilage leads to the collapse seen during exercise. Although we have limited experience with this odd condition, these horses do not respond to laryngoplasty. Treatment at this time is still experimental.

This form of collapse showed in Figure 13B has been reported in the Norwegian cold blood trotter and we have observed it in Saddlebred, Hackney pony, Warmblood and Thoroughbred racehorses. Catherine Fjorbakk’s PhD thesis is an exhaustive explanation of the condition. The condition is associated with poll flexion leading to an external compression of the larynx. This occurs because poll flexion leads to a more cephalic position of the larynx and narrowing of the laryngeal diameter. The source of the intra-mandibular external compression of the larynx is not identified but is clearly obvious on the CT exam. Although some histopathological evidence of RLN is present, the prevalence of this histopathological lesion is similar to those of nonaffected controls. These animals do not respond well to triculocordectomy with or without laryngoplasty. A device that restricts poll flexion has been shown to resolve this problem.

The form of collapse shown in Figure 13C has been reported by at least three different groups and is not well understood. In a recent paper calling for a plea for consensus on nomenclature of upper airway obstruction, it was recommended to refer to this condition as ventromedial luxation of the apex of the corniculate process of the arytenoid cartilage (VLAC). The condition may be unilateral or bilateral, may be obstructive or not, and can be observed in horses that also have RLN, although this is rare in the author’s experience. In humans, a similar endoscopic appearance is observed associated with a posterior (i.e., dorsal) cleft of the cricoid cartilage. A post-mortem exam has not been performed in any affected horses but an esophageal ultrasound was performed in one case and failed to detect a cricoid cleft. Barakzai has reported the post-mortem exam of an affected Clydesdale horse and has suggested that the condition is due to an abnormally wide transverse arytenoid ligament. Treatment at this time is still experimental.

Arytenoid Chondritis

Horses affected with arytenoid chondritis present with various degrees of restriction or inability to abduct their affected arytenoid cartilage(s). The condition can be unilateral or bilateral. Current evidence of this condition is a result of a progressive infection following mucosal injury to the body of the arytenoid cartilages. The cause of the direct mucosal trauma has been associated with direct trauma from endoscopy, attempts at nasogastric intubation, inhaled foreign body (from dirt tract?), or more violent evidence of coughing when both vocal process contact each other. Excessive vocalization has been hypothesized as a cause. The author has observed an association between subepiglottic lesions and these mucosal lesions. By inspection it seems that the ventral-lateral edge of the epiglottis contacts the medial surface of the arytenoid cartilage and creates a mucosal ulceration (Fig. 14). Chondritis of the arytenoid cartilage is believed to start with a mucosal ulcer, which extends through the basal membrane into the arytenoid cartilage.
The etiopathogenesis was pursued in an experimental study where mucosal ulcers were created by nasotracheal intubation in 21 horses. In 52% of these horses, the lesions were healed within 1 week and another in 3 weeks. None of the horses developed granuloma or clinically evident chondritis. This is consistent with the clinical finding that these mucosal lesions are rare and only a small percentage of horses with mucosal injury progress to intraluminal granuloma or chondritis. Smith et al., 2006 reported in a large survey of 2317 New Zealand Thoroughbred racehorses (range, 15–24 months of age) only 33 horses (1.2%) had arytenoid mucosal lesions including five with overt chondritis. Horses with mucosal lesions were not statistically different than control in terms of number of horses that raced. Kelly et al., 2003 reported on 3312 post-sales endoscopies in Australian Thoroughbreds and 21 horses (0.63%) had arytenoid mucosal lesions. There was an apparent prevalence of farms from which they originated and were predominantly female. Five of the 21 were known to develop intraluminal granulomas and only one of them developed chondropathy. The low percentage of mucosal ulcers progressing to arytenoid chondritis is also consistent with the low prevalence of chondritis in Thoroughbred racehorses ranging from 0.21 to 0.22% (note that prevalence data have not been reported in North America).

The pathogenesis of arytenoid chondritis is believed to be mucosal trauma to the medial surface of the arytenoid cartilage leading to mucosal ulceration. If the lesion does not extend past the basement membrane, epithelization occurs in 1–4 weeks. If the trauma does extend past the basement membrane, bacterial invasion of the perichondrium leads to formation of granulomas and possibly the development of septic chondropathy. When the arytenoid cartilage geometry enlarges, the arytenoid cartilage has progressive reduction in abduction despite normal neuromuscular laryngeal anatomy. Ultrasound now allows a much more precise definition of the extent of the arytenoid lesions (enlargement of body of the arytenoid cartilage) and the reader is referred to the earlier section in diagnosis. This is particularly important as in theory, resolution of the granulomas yields restoration of full abduction function, whereas partial arytenoidecotomy does not restore airway mechanics to normal. The other important contribution of ultrasound in the management of arytenoid chondropathy is the identification of an abscess surrounding or in the cartilage. In those cases, drainage of the abscess can restore full arytenoid abduction function.

In the veterinary literature, medical treatment consisting of local anti-inflammatory agents has been reported to be associated with a high success in treating mucosal lesions. The author has also recommended the use of hyperbaric therapy. The triage issues are based on the answers to the following questions:

- Are/is the granulomas obstructive?
- Does the granuloma risk causing a mucosal lesion to the other side?
- What is the status of abduction of the affected cartilage?

If granulomas are small, they are also treated and if this modality is not successful then surgical resection of the granulomas is recommended. It should be pointed out that recurrence of the granulomas is possible and the author would estimate this to be approximately 30%. Similar problems have been seen in humans and many different techniques have been investigated to reduce the recurrence of vocal process granulomas, which is approximately 22–44%. The principles of treatments seems similar in the human patient counterpart where a recent analysis of treatment for vocal process granuloma was performed.

A partial arytenoidecotomy is recommended on a performance horse if abduction is compromised. A sub-total may be considered on a pasture sound animal. The reader is referred to the above discussion on Partial Arytenoidecotomy.
5. Epiglottic Disease

Entrapment

Etiopathogenesis

This abnormality is seen when the loose glossoepiglottic fold becomes entrapped over the dorsal aspect of the epiglottis. Anatomically, the glossoepiglottic fold allows epiglottic retroversion during swallowing. This movement of the epiglottis is an important part of the deglutitive airway protective mechanism allowing the base of the epiglottis (the dorsal surface) to approximate against the adducted vocal cords and arytenoid cartilage.

Epiglottic entrapments are seen with three broadly different presentations. It can be a congenital deformity (often associated with cleft palate), or an acquired condition, predominantly racehorses, resulting in a respiratory obstruction and/or abnormal upper respiratory noise, and finally, in mature non-racehorses it can be an acquired condition resulting in coughing, nasal discharge and/or dysphagia.

The cause/etiology of the congenital condition is unknown, but when associated with cleft palate, it seems to be protective of tracheal penetration of feed material. The acquired condition is not well understood. It can be seen as a sequel to an epiglottic injury (acquired or iatrogenic) leading to inflammation and swelling of the sub-epiglottic tissues and dorsal displacement (i.e., entrapment) of the glossoepiglottic fold over the epiglottic cartilage. Inflammation and infection into the epiglottis has been observed and can result in a loss and deformity of the cartilage matrix so the glossoepiglottic membrane is relationally redundant. As entrapment becomes chronic, they become thickened and ulcerated over time.

The significance of the entrapment is variable. It may not be affecting the horse's performance, in some thin and short entrapments, no obstruction is present. This is consistent with a couple surveys indicating no negative association between the presence of epiglottic entrapment and racing performance. In other cases, the entrapment seems to cause an expiratory obstruction for which the severity correlates with the caudal extent of the entrapment. During exhalation, the entrapment is lifted by the flow of air causing an obstruction. It has been reported that chronic entrapment then becomes thicker and ulcerated and causes pressure necrosis on the tip of the epiglottic cartilage.

From the authors' perspective it is difficult to determine what came first — the entrapment or the epiglottic chondritis.

Diagnosis

The diagnosis is generally straightforward with the persistent entrapping membrane over the dorsal aspect of the epiglottis. Ary-epiglottic entrapment differs from DDSP insofar as the outline of the epiglottic cartilage is covered by the entrapment and can be recognized as a separate structure from the soft palate (Fig. 15A). Intermittent entrapments may be more difficult to identify as they are often not entrapped at the time of the exam. Many intermittent entrapments that are not entrapped on resting examination may be made to entrap by inducing swallowing. This is a mechanism by which swallowing-induced entrapment is not understood. Alternatively, one can place local anesthetic in the nasopharynx including the epiglottis and sub-epiglottic tissue after sedation. A laryngeal forceps is then used to grasp the sub-epiglottic tissue and force an entrapment to observe if it stays in
Treatments

The principle of treatments of epiglottic entrapment is axial transection of the glossoepiglottic fold, or wedge resection of the entrapping membrane. Most commonly the procedure is performed in the sedated horses under endoscopic control thru the nasopharynx. However, it can be performed on the horse standing through the oropharynx. Axial division can also be performed on a short-acting general anesthesia through the oropharynx. Laryngotomy under general anesthesia is reserved for more severe presentations with very thick and sometimes adhered ary-epiglottic membrane to the epiglottis. The division of the membrane can be achieved with a curved-hook bistoury, a shielded hook bistoury, electro-coagulation, snare, and laser surgery. This is a relatively successful procedure associated with a recurrence rate ranging from 10 to 40%. The commonest complication to avoid is epiglottitis. Damage to the epiglottis can occur with any of the techniques and it is the single most important technical aspect to focus on during the procedure. Technical tips will be presented to minimize the occurrence of these risks. DDSP is the second most common complication after treatment for epiglottic entrapment. Although the root cause of the permanent DDSP is not described, the author believes they are a sequel to subepiglottic ulceration and/or epiglottitis either as a response to direct iatrogenic damage, prior epiglottitis, or problems related to secondary wound healing in the sub-epiglottic area.

6. Epiglottitis

Etiopathogenesis

Epiglottitis is an inflammatory condition that may be of viral or bacterial origin. Bacterial and viral epiglottitis are apparently common in humans and are a potential life-threatening event because of airway obstruction. Severe airway obstruction is a rare occurrence in horses and they generally present for milder obstruction, abnormal upper airway noise, and sometimes dysphagia. Our understanding of the true cause is extremely limited in veterinary medicine. Presumably, local inflammatory agent (i.e., viral, surgical trauma) leads to epiglottitis. Alternatively, a foreign body perforation of the sub-epiglottic mucosa leads to bacterial invasion with marked mucosal swelling. If the infection extends through the basal membrane of the epiglottic cartilage, this leads to an epiglottic chondritis. In the acute phase soft tissue swelling predominated, whereas in the chronic situation, deformity of the epiglottic cartilage is seen. This condition may be quite painful and result in caudal retraction of the larynx and DDSP or coughing and/or dysphagia.

Diagnosis

The diagnosis is driven by the clinical signs that dictated an endoscopic examination. Epiglottitis is characterized by marked swelling of the sub-epiglottic membrane with or without sub-epiglottic ulceration. It is important for the clinician to recognize the loss of normal border of epiglottic cartilage as epiglottitis (Fig. 15B) and differentiate this from epiglottic entrapment (Fig. 15A). In both cases, the scalloped edge of the epiglottic cartilage is lost but in cases of epiglottic entrapment there is a finite edge to the lateral aspect of the ary-epiglottic (i.e., glossoepiglottic) fold vs just being swollen. If there is infection of the epiglottic cartilage, a dorsal bulge (Fig. 16A) or ulceration is observed.

Treatments

Acute epiglottitis are managed by local anti-inflammatory treatment (see earlier description) and the prognosis is good if there is no epiglottic chondritis. Acute epiglottitis is not a surgical condition unless a tracheostomy is needed to relieve dyspnea, which is very rare. If epiglottic chondritis is present, the prognosis may decrease as deformity and inflammation of the epiglottic cartilage may predispose to intermittent DDSP. The prognosis may become guarded as severe epiglottic deformity is associated with persistent DDSP.

If an epiglottic abscess is present, the author recommends surgical drainage which is achieved with a minimal opening/incision in the epiglottic cartilage. This may be achieved using an endoscopic laryngeal scissor and laser surgery followed by surgical lavage (Fig. 16B and C).

Sub-Epiglottic Pathology

Etiopathogenesis

In a study of 91 horses received for post-mortem exam from a southern California racetrack, the prevalence of sub-epiglottic pathology was 7.7%. There are no evidence-based data to explain the etiology of these lesions. It has been hypothesized that sub-epiglottic ulcer and granulomas are secondary to bacterial infection although sometimes the inflammation surrounding the ulcer seems minimal. In terms of infectious agents, one study of the ulcer beds revealed low to moderate numbers of mixed bacterial colonies and no fungal elements.
It has been proposed that trauma from soft palate ulceration, foreign body while swallowing (i.e., dirt, sharp ends from diet) or intermittent ary-epiglottic entrapment is the original cause of mucosal irritation. The lesions are typically chronically active with granulation tissue and hyperplastic epithelial margins.

These lesions are thought to predispose the horse to intermittent or persistent DDSP and can be seen in association with ulcers of the caudal free edge of the soft palate.

Diagnosis
Lesions of the sub-epiglottic area are particularly easy to miss unless the swelling or disease extends beyond the lateral border of the epiglottis. The author has seen a fair number of sub-epiglottic lesions in association with mucosal lesions on the medial
aspect of the arytenoid cartilage (Fig. 14). An observation of such lesions on the arytenoid cartilage would suggest the need to explore the sub-epiglottic tissue. Blea and Arthur emphasized the importance of and described the manipulation needed to get a good examination of the sub-epiglottic tissue (glossoepiglottic fold). The horse should be sedated and liberal application of local anesthesia is needed to the area. A “puddle” of local anesthesia can be made to rest under the epiglottis cartilage if the head is elevated to an appropriate level. Then a blunt “laryngeal elevator” or an equine laryngeal forceps is used to elevate the epiglottis (Fig. 17). Without evaluating the epiglottic cartilage, it is difficult to have a precise and complete evaluation of the sub-epiglottic tissues.

Management

The element of treatment of this condition includes removing the horse from active training with the combination of local anti-inflammatory and systemic antibiotics. They are slow to heal and often do not fully heal. The author has tracked the healing of a few of them over 2–3 months. Empirically, the author often used sucralfate (20 cc at 250 mg/mL or three tablets in 10 mL of water [1 g/tab]) three times a day to coat the area. There are no data to confirm whether any of the medication reaches, adheres to, or benefits the area. In addition, 20–30 cc glycerin can be given orally prior to training to protect a freshly healed area.

7. Conclusion

The cartilage in the upper airways crosses the finish line first and is therefore clearly the most important cartilage in the equine body. Despite that, as in many aspects of equine veterinary medicine, level 1 evidence-based data is lacking to precisely guide the optimal management course of our patients. Understanding the etiopathogenesis of many of these conditions is still surprisingly limited. Despite the lack of information, one must still recognize and treat patients; a key factor is recognizing and interpreting the different nuances of the clinical presentation. It is hoped that in the future more evidence-based data will be gathered to guide our refinements in treating and managing the aforementioned conditions. In the author’s opinion, the goals should always target less-invasive approach with a quicker return to function.

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Declaration of Ethics

The Author has adhered to the principles of the Veterinary Medical Ethics of the AVMA.

Conflicts of Interest

Dr. Norm Ducharme receives sales income from the use of the Cornell Collar license from Cornell University. Dr. Ducharme is listed as one of the inventors of the Cornell Collar and receive royalties from Cornell University. Dr. Ducharme is listed as one of the inventors on the equine neuroprosthesis patents owned by MED-EL Medical Electronics. Dr. Ducharme’s rights have been assigned to Cornell University. Their financial and business interests have been reviewed and managed by the University in accordance with its conflict of interest policies.

References and Footnotes


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Climbing Mt. Debt: Integrating Student Loan Repayment Into a Personal Financial Wellness Plan

Tony Bartels, DVM, MBA

Navigating and objectively assessing the rapidly evolving student loan repayment options can be a challenge and significant source of stress for the busy veterinary practitioner. This session will describe how you can use your debt-to-income ratio, your average monthly student loan interest accrual, your income and family size information, and your short- and long-term career and family plans to cater an income-driven repayment option that allows you to integrate student loan repayment into a strong financial wellness plan. Author’s address: Veterinary Information Network, 777 W. Covell Blvd., Davis, CA 95616; e-mail: tonyb@vin.com © 2016 AAEP.

1. Introduction

For those entering veterinary school in the Fall of 2016, the estimated total cost of attendance (tuition + fees + average living expenses, assuming a 4% increase each year) for 4 years ranges from $147,000 to more than $393,000 depending on the school, residency status, and borrowing needs. Although scholarships can help, most veterinary students finance their education through federal student loans. For those who do, interest now accrues on a majority of their loans during vet school, which will further increase their total cost of attendance.

With the increases in cost of attendance outpacing starting salaries, repaying educational debt can be challenging for the recent veterinary graduate.

During the Climbing Mt. Debt session, we will discuss how to analyze your student loans and the various options available, including income-driven repayment and the associated “side effects” of the various plans.

The objectives of the Climbing Mt. Debt session are below:

- Know your student debt
- Know your repayment options
- Know your finances
- Know the challenges and side effects of various repayment strategies
- Integrate your loan repayment into a comprehensive financial plan

2. Solution

Income-driven repayment (income-based repayment [IBR], pay as you earn [PAYE], and revised pay as your earn [REPAYE]) are recent federal student loan programs that base your minimum monthly payment on your taxable income, family size, as well as any federal student debt your spouse may have. As your income and family circumstances change, your federal student loan payment changes with you. This will allow you to diversify your monthly...
cash flow allocation and include items considered to be financially healthy, such as: building an emergency reserve, saving for retirement, planning for a family, buying or starting a practice, as well as other short- and long-term financial goals.

However, when we base student loan payments on income, the total balance may grow over time due to negative amortization. As a result, income-driven repayment options have the potential to culminate in a forgiven balance that may be treated as taxable income at the end of repayment. Therefore, this strategy requires the diligence and understanding to move from a debt “pay off” to “management” mindset as we often must account for a sizeable tax payment due in the last year of repayment.

Knowing how to manage student loan(s) through an income-driven plan and prepare for the potential forgiveness, as well as being able to compare this strategy against traditional repayment methods may save you tens to hundreds of thousands of dollars over the course of student loan repayment.

3. Results
Let’s consider a 2016 graduate who borrows $175,000 for veterinary school and accumulates $20,000 of interest during school. This graduate’s starting repayment balance will be $195,000 with a weighted average interest rate of 6.22%. We will assume this graduate’s first-year salary is $45,000, increases to approximately $62,000 per year, then 3.5% per year on average for the next 25 years. For the purpose of this simulation, we will assume a family size of one for the duration of student loan repayment. Figure 1 is a snapshot of total projected repayment costs under various programs run via the VIN Foundation Student Loan Repayment Simulator.

For those who already have a family or have marriage and children in their future, your family size, as well as spouse’s debt and income, play a major role in simulating your repayment. Let’s consider the same 2016 graduate above with a starting repayment balance of $195,000 at 6.22% and same income assumptions. This time, let’s assume this graduate is married in 2018 to a small animal veterinary practitioner spouse who makes $70,000 per year and carries a $170,000 federal student loan balance. They plan to file their taxes jointly when married. They will have one child in 2019 and a
second in 2021. Figure 2 is a snapshot of the total projected repayment costs run via the VIN Foundation Student Loan Repayment Simulator for the graduate only.

The number and types of simulations that can be run are only limited by the number of personal situations we can document or imagine. We can run some additional simulations during the sessions to account for other scenarios like filing your taxes separately from your spouse, as well as significant increases to income later in repayment due to practice ownership. Many of these simulations will depend on how the borrower and spouse are paid vs how their income flows through their federal income tax returns. You can also simulate your own scenarios using the VIN Foundation Student Loan Repayment Simulator.

4. Discussion

Understanding your student loan repayment options depends on the specifics of each circumstance. Variables that contribute to the complexity include your borrowing history, your various loan types, your various interest rates, your current loan repayment plan, your income and family size, how you document your income, as well as your career and financial goals.

The first step is understanding which repayment plans you can use. The second step is deciding which plan you should use, and the third step is knowing how to analyze and evaluate your repayment plan at least yearly or whenever your income and family situation changes.

Simulation results vary greatly for each situation and the plan must be re-assessed each year or whenever there are changes to your family and financial situation.

From the two simulations provided in the results, we see there can be significant savings using income-driven repayment options vs more traditional methods, especially when the borrower’s debt-to-income ratio is greater than 2. The income-driven repayment plans are primarily designed to help you navigate those periods where your debt exceeds your income. The length of time that situation persists determines whether veterinarians should plan for a tax liability at the time of forgiveness.

When simulating income-driven repayment, we must consider the taxes due at forgiveness and...
make sure we work the projected amount due into a long-term repayment plan to accommodate this expense the year it occurs. If we do so as part of a comprehensive financial plan, you may save money over the course of repayment while being able to meet your other financial goals.

Income-driven repayment also requires the diligence to provide the required documentation each year or whenever your financial or family situation changes appreciably. Although the initial learning curve is steep, the potential savings and flexibility offered can often be worth the effort.

Acknowledgments

Analyzing veterinary student loan repayment has been an issue near and dear to the heart of Paul Pion, DVM, DACVIM (Cardiology), co-founder of the Veterinary Information Network (VIN); and Tony Bartels, DVM, MBA. Tony is a 2012 Colorado State University graduate and employee of the VIN. He and his wife have more than $400,000 of veterinary school debt they manage using the federal income-driven repayment plans. He also contributes to VIN Foundation initiatives that involve student debt. Through outside donations and the support of VIN, much of the information discussed in this paper can be found at www.vinfoundation.org.

There are additional resources available for VIN members, where Dr Bartels works as a VIN consultant, helping veterinary colleagues work through the specifics of their loan repayment “cases,” similar to how veterinary medical cases and questions are discussed across VIN.

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

Website Resources

6. Link to online presentation to be used at the AAEP Annual Convention. http://prezi.com/jpuy6nu5aaec/?utm_campaign=share&utm_medium=copy&rc=ex0share.
Diagnosis and Management of Proximal Metatarsal and Tarsal Injuries Using MRI

Matthew T. Brokken, DVM, DACVS, DACVSMR

This paper will serve to highlight abnormalities noted with magnetic resonance (MR) imaging in the proximal metatarsal and tarsal regions (particularly MR findings of horses with lameness localized with some type of subtarsal block) and treatment methods based off of the results of the findings. The paper will also discuss current diagnostic analgesia methods and their limitations when localizing lameness in this region. Author’s address: The Ohio State University, 601 Vernon Tharp Street, Columbus, OH 43210; e-mail: brokken.1@osu.edu. © 2016 AAEP.

1. Introduction
The proximal metatarsal and tarsal regions are a complex and very important source of lameness in the performance horse. Horses in a variety of disciplines and ages may manifest with pain associated in this region. Recently, the use of magnetic resonance (MR) imaging (MRI) in this region has served to improve our recognition of injuries in this region. However, there are horses in which lameness persists or fails to improve despite treatment. Having amassed a moderate number of clinical cases with MRI (this paper will serve only to address high-field MR images) we are slowly developing treatment strategies based on the MR appearance of lesions and thus moving toward more-appropriate treatment. However, it is important to note that we are in the early stages of this and the learning curve is steep and all successes and failures should be scrutinized based on the clinical presentation of the horse, the MR findings, the treatment(s), and ultimately how the horse responds to the treatment(s).

2. Diagnostic Analgesia
Lameness problems in the proximal metatarsus can be difficult to accurately diagnose because affected horses frequently do not have clinical signs (heat, pain, swelling) that allow the lameness to be localized to this area. Frequently, the localization of proximal metatarsal lameness is accomplished by observing improvement after diagnostic local analgesia. There are multiple techniques for desensitizing the proximal aspect of the plantar metatarsus; local infiltration, high 4- or 6-point, and deep branch of the lateral plantar nerve (DBLNP). However, confusion exists when interpreting the results due to the lack of specificity of local analgesic techniques. Many horses do not block completely sound with local analgesia of the proximal metatarsus. This is likely related to the nature of the block and dependency on local diffusion throughout the region. In many cases a combination of intra-articular and regional anesthesia is crucial to accurately isolate the lameness to this specific area. Even then, there can be confusing results due to
diffusion from one site to another. In a study that performed MRI examinations on horses that blocked to a DBLPN block, only 25 of 46 limbs (∼54%) had injury of the proximal suspensory ligament or its osseous attachment.2 Another study found that limbs that responded to analgesia of the proximal metatarsal region (35.7%) had more severe changes in the distal tarsus.3 One of 12 horses with lower hock pathology demonstrated on high-field MR images also improved with a subtarsal block.4

Recent studies have investigated the in-vivo distribution of contrast while performing variations of the single injection site technique to block the DBLPN and thus, hypothetically, the proximal suspensory ligament (PSL). One study investigated using two techniques with low (2 mL) and high volumes (8 mL) of a mixture of contrast and mepivacaine.5 Contrast diffusion was greater proximally in the technique with proximal angulation (~45° distal to proximal and 20 mm distal to the head of the lateral splint bone) compared with the technique that was perpendicular to the limb and 15 mm distal to the head of the lateral splint. The authors also concluded that despite significant differences, contrast diffusion could be variable irrespective of the technique or volume used. They also concluded that the high-volume of injection may have increased the risk of false-positive results. With regard to accidental injection of adjacent synovial structures, 16% of injections (5/32) were in the tarsal sheath (found with both techniques) and 6% of injections (2/32) were in the tarsometatarsal joint (all with the perpendicular technique ~15 mm distal to the head of the lateral splint bone). Interestingly, six of seven synovial injections were in the right hindlimb (suggestive of difficulty of “cross-handed” injection for right-handed individuals).

In another study by Contino et al.,6 the concentration of mepivacaine was investigated in the tarsometatarsal joint after the single injection (DBLPN) technique (~20 mm distal to the head of the lateral splint with 3 mL perpendicular to skin). The authors found that 25% of limbs had a sufficient amount of mepivacaine in the joint to produce analgesia. In addition, they also performed a contrast study with a similar injection technique and found that 37.5% of limbs (3/8) had contrast in the tarsal sheath and no contrast was found in the tarsometatarsal joint.

Due to the possible confusion associated with this region when performing diagnostic analgesia, the author prefers to perform a block of the lower two tarsal joints at some point during the diagnostic workup; typically after improvement from a subtarsal block. In horses with radiographic evidence of lower-hock osteoarthritis, performing analgesia of the lower hocks after a positive response of a subtarsal block is very important to determine how to proceed in the diagnostic and therapeutic workup. In addition, taking into consideration the degree of lameness of the horse as well as historical information (i.e., horse typically has hocks injected and now has become nonresponsive to the injections and lameness has worsened is a typical presentation of proximal suspensory injury or, less commonly, bone injury of the lower tarsus).

3. Diagnostic Imaging (MRI)

After localization of lameness to the proximal metatarsal region, radiographic and ultrasonographic examination should be routine. If the diagnosis is not determined or if it is inconclusive, MRI may be performed. Based on the limitations already discussed regarding diagnostic analgesia in this region, it is critical that the tarsus (at least from the proximal intertarsal joint distally) also be included in an MR examination of the proximal metatarsal region (Fig. 1). Depending on the MR unit and the individual variation between horses, positioning of the horse to this level may be challenging. Standing MR images of this region are certainly possible and can provide valuable information; however, motion artifacts are common and field-of-view limitations may make it difficult and impractical to scan such a large region. Due to the concern about motion, diagnostic fat-suppressed images (which can be very helpful for bone injuries, etc.) can be very difficult to acquire in the standing patient. In addition, the author believes that the contralateral limb should be scanned if possible (even if it is an abbreviated scan) due to the propensity for bilateral disease in this region.

4. Abnormalities Identified With MR Imaging

Proximal Suspensory Injury

There are several types of injuries to the proximal suspensory ligament that have been identified with MRI. Typically, there is increased size of the ligament with areas of increased signal intensity; typi-
cally more dorsally located within the ligament (Fig. 2). These areas of increased signal (fiber disruption) can be present at the level where the ligament attaches to the proximal cannon bone and/or just distal to the attachment with extension distally for several centimeters. The author has also identified horses with injury to the proximal extension of the suspensory ligament in the distal tarsal region (Fig. 3) at or near its attachment onto the third tarsal bone.

With regards to enlargement, there are also horses in which there is irregular and thickened tissue at the border of the ligament; typically associated with the lateral splint bone. At surgery, these horses have adhesion/increased tissue formation that connects from the ligament to the splint bone (Fig. 4).

In addition to the ligamentous injury, some horses will also have osseous reaction in the plantar aspect of the proximal cannon bone at the attachment of the PSL. Typically, this is an area of low signal intensity within the plantar medullary cavity; representative of sclerosis on proton density sequences. This also demonstrates the fact that when most proximal injuries are noted, they are more chronic in nature. In some horses, there will be increased signal intensity within the plantar medullary cavity/cortex on the fat-suppressed images. This is indicative of a more acute injury at the ligamentous attachment (Fig. 5).

**Tarsal Abnormalities**

Examination of the distal tarsal region with MR can also demonstrate damage associated with the articular surface of the tarsometatarsal and distal intertarsal joints. In particular, MR imaging has allowed us to identify the horses with lower hock cartilage/bone damage associated with the plantar aspect of the joints as well as surrounding the intertarsal ligaments (Fig. 6). In addition, there have been horses with osseous cyst-like lesions noted in the distal tarsus that MR imaging allows characterization of the activity and joint involvement. Primary bone injuries have also been identified in the tarsus with typical locations adjacent to the intertarsal ligament in the central or third tarsal bones, the head of the splint bones, or in the plantar aspect of the tarsus (Fig. 7, A and B).
Other Abnormalities
In horses that have lameness localized to the proximal metatarsal/tarsal region, other abnormalities have been reported with MRI that should not be overlooked as a source of lameness. Davis et al\(^7\) described four horses with injury to the lateral digital flexor tendon at the level of the proximal suspensory ligament. All horses had lameness localized to the proximal metatarsal/distal tarsal region before MRI. Based on the MR abnormalities in the lateral digital flexor tendon, all horses responded positively to tarsal sheath anesthesia.

5. Treatment
Proximal Suspensory Injury
Whereas most horses with acute proximal suspensory desmitis of the forelimb respond well to stall rest and a regime of controlled exercise, hindlimb injuries have a much lower prognosis with conservative therapy.\(^8\) In addition, there is a large number of horses where lameness persists or reoccurs with exercise. Some have hypothesized that the poor prognosis and persistent lameness is due to a compartment syndrome from the enlarged PSL causing compression of the plantar metatarsal nerves (particularly the DBLPN) due to the restriction from the inelastic plantar metatarsal fascia. Pathologic examination of the DBLPN in horses with proximal suspensory desmitis revealed evidence of chronic nerve compression.\(^9\) Recently, new surgical procedures have been aimed at decompression, desensitization, and promoting angiogenesis of the injured PSL. The most popular surgical procedure of late has been neurectomy of the DBLPN and plantar fasciotomy as described by Bathe.\(^10\) It is believed that the thick plantar metatarsal fascia restricts the expansion of the injured PSL leading to a local compartment syndrome and compression of the plantar metatarsal nerves. The premise for developing this surgical procedure was that persistent lameness is due to both compartment syndrome and chronic local nerve irritation. In horses with desmitis of the PSL without other adjacent abnormalities, neurectomy and fasciotomy alone are performed. In horses with severe ultrasonographic abnormalities in the ligament, these horses are injected with some type of autologous cell-based therapy in addition to the surgery. Bathe reports success rates of 79% in horses that underwent neurectomy and fasciotomy alone. With cell-based injections and surgery, the success rate was reported to be 84%. Only 55% of those horses with ligament and osseous damage returned after surgery. In the publication by Dyson and Murray, 78% of horses with primary proximal suspensory desmopathy without major conformational issues or other concurrent lameness issues were managed successfully with neurectomy and fasciotomy (returned to full athletic function at their previous level for >1 y).\(^11\) They also concluded that surgery is contraindicated in horses with straight hind-limb conformation or excessive extension in the metatarsophalangeal joints.

It still remains unknown what effect performing fasciotomy alone without neurectomy and vice versa has on horses with proximal suspensory injury. Information presented by Tóth et al\(^9\) suggests that just excising a portion of the deep branch of the

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**Fig. 5.** Transverse fat-suppressed image of the proximal metatarsus depicting increased signal in the plantar medullary cavity of the third metatarsal bone (arrow) indicating an active/acute injury.

**Fig. 6.** Sagittal fat-suppressed image of the proximal metatarsus/distal tarsus depicting loss of joint space of the distal intertarsal joint (arrows) which extends into the region of the intertarsal ligament (arrowhead).
lateral plantar nerve may be sufficient to allow horses with proximal suspensory desmopathy to return to performance. In contrast, Hewes and White\textsuperscript{12} report a procedure of desmoplasty and fasciotomy for hindlimb proximal suspensory injury that allowed 87% of horses to return to full work, suggesting that decompression and or ligament splitting may be effective in returning horses to performance. In addition, there are veterinarians who just perform a fasciotomy (typically along with some type of intraleisional regenerative therapy) with reported results similar to that of performing a fasciotomy and neurectomy.

In horses with osseous abnormalities at the attachment of the PSL to the cannon bone, some have suggested that performing osteostixis or “scoring” the boney surface may help some of these horses return to exercise\textsuperscript{12,13}

In horses with concurrent osseous and ligamentous injuries, advanced imaging will allow determination if the osseous injury is acute or chronic (i.e., increased signal on the fat-suppressed images in the proximal third metatarsal bone at the PSL origin suggests an acute bone injury). In horses with acute osseous injuries, appropriate time to allow the bone to remodel is necessary (the author prefers ≥60 d stall confinement). Additional treatment for the concurrent PSL injury could also be performed during this time. The author prefers not to perform neurectomy/fasciotomy in horses with acute osseous injuries noted on MRI.

Tarsal Abnormalities
For horses diagnosed with primary damage in the distal tarsal region, treatments typically consist of cortisone, with or without hyaluronic acid, injection. If a primary bone injury is detected on MR images with little, if any, joint involvement, these horses typically respond well to a 90-day stall rest with limited handwalking protocol to allow time for the bone to remodel. In horses with severe cartilage damage/osteoarthritis or horses that become nonresponsive to intra-articular cortisone injections, a variety of facilitated arthrodesis techniques have been advocated. Surgical drilling or passing a diode laser across the joint seems to be the most common surgical procedures currently performed. In addition, injection of ethyl alcohol has been studied to aid in the fusion of the lower hock joints. However, there is concern about communication with the proximal intertarsal joint. Horses treated with laser surgery or ethyl alcohol typically are more comfortable and less lame compared with horses that have drilling performed\textsuperscript{14}. However, horses with marked osteoarthritis can make laser surgery (without predrilling) and ethyl alcohol injections more difficult or impossible to perform.

6. Summary
In conclusion, determination of the exact cause of lameness in the proximal metatarsal/tarsal region can be very difficult using diagnostic analgesia and traditional imaging modalities. MRI is a valuable diagnostic modality that allows diagnosis of injury in horses with lameness localized to these regions. The ability to accurately diagnose the source of lameness is important in selecting treatment that will maximize the chance to return to performance. Future research should be aimed at describing what type of specific treatment should be performed on horses with specific MRI findings and the results of treatment.
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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnote

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Use of MRI to Evaluate Fetlock Region Pain in the Sport Horse

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1. Introduction

The metacarpo(tarso)phalangeal joint (MPJ) or fetlock joint is often a source of lameness in sport horses of many different disciplines. In a recent survey of causes of lameness in different horse breeds, synovitis or osteoarthritis of the metacarpo-phalangeal joint was consistently listed as one of the 10 most common causes of lameness in all categories of sport horses surveyed. Fetlock pain was ranked more highly as a cause of lameness in racehorses than in nonracing sport horses. However, lameness referable to the fetlock region can sometimes be difficult to accurately diagnose. A careful and complete examination of the distal limb of the horse will often indicate the fetlock as a clinical problem.

A positive distal limb flexion, frequently thought to be associated with a MPJ problem may actually be due to lameness from elsewhere on the distal limb. In addition, the clinical examination may not conclusively identify the MPJ as the source of lameness. Confirming the MPJ region as the source of pain is critical to direct imaging of the appropriate area of this region. Placement of local analgesia directly into the MPJ (intra-articular or intra-synovial) often results in a rapid and significant resolution of the lameness associated with the fetlock joint. In contrast, some conditions that affect this joint (particularly in young racehorses in race training) do not respond to intra-articular analgesia but require perineural (regional) diagnostic analgesia to resolve the lameness. Regional diagnostic analgesia should be performed in a distal-to-proximal sequence with the clinician being cognizant that properly placed nerve blocks can anesthetize structures proximal to the site of injection.

If the fetlock is considered the source of lameness then intra-articular analgesia of the MPJ should be performed first. If this is negative, analgesia of the digital nerves at the level of the base of the sesamoid nerve block should then be performed, eliminating the distal limb as a source of pain. If this is negative then a low palmar/plantar nerve block to isolate the MC region as the source of the lameness should be performed. Unfortunately, it is now commonly recognized that the blocking patterns just described are not always accurate. Abaxial nerve blocks can effectively anesthetize the palmar/plantar aspect of the fetlock joint and an intra-articular fetlock joint block may effectively block some of the distal sesamoidean ligament injuries. In addition, it has been found that on occasion a well-placed palmar digital nerve block can quite effectively block out a fetlock region problem due to retrograde flow of the anesthetic solution. Intrathecal anesthesia of the dig-
ital flexor tendon sheath (DFTS) was effective at improving lameness in 22 of 22 horses with magnetic resonance imaging (MRI)—confirmed distal sesamoidean ligament (DSL) injury. In addition, intra-articular anesthesia improved lameness in 11 of 19 horses with DSL desmitis near their origin on the base of the proximal sesamoid bones (PSBs) and three of three with lameness due to collateral ligament (CL) injury.3

Once the MPJ is determined to be the source of the pain, diagnostic imaging is directed to evaluate the bone and soft tissue structures of the joint. Given that many injuries that occur in the fetlock involve multiple structures, careful assessment of both bone and soft tissue structure involvement should be performed. Knowing the specific structure(s) and the severity of injury is critical to appropriately determine the prognosis and appropriately treat and rehabilitate injuries of this area. Radiographic, ultrasonographic, and occasionally nuclear scintigraphic examinations are routinely used to evaluate the metacarpophalangeal joint (MCJ). Radiographic examination and nuclear scintigraphy are considered bone imaging techniques and ultrasonography a soft-tissue-imaging technique. Each of these imaging techniques has known limitations when assessing the MPJ. When clinical examination and diagnostic analgesia indicates the fetlock joint as the source of pain but these examination techniques provide little definitive results MRI examination is indicated.

MRI is now considered the gold standard for imaging the distal limb of the horse. It can provide information about both bone and soft tissue while also demonstrating both pathologic and physiologic changes in tissue. The choice of protocols is determined by the type of scanner, the region under scrutiny, and the preference of the attending clinician. Consequently, protocols often differ between hospitals. Sequences and image planes should be standardized to allow for comparison between limbs and between horses. Deviation from the standardized protocol complicates interpretation and may lead to misdiagnosis. Increasing scanning times prolongs recumbency, which can result in post-anesthetic complications. The best assessment of an anatomical region requires images to be obtained in three planes, sagittal, dorsal, and transverse. At North Carolina State University the fetlock region is examined using a wrap-around extremity radiofrequency coil, with the fetlock positioned in the isocentre of a short-bore, flared-end 1.5 Tesla Siemens Symphony magnet. The examination consists of sagittal, transverse, and dorsal dual-echo sequences (2D T2 and proton density), sagittal and transverse short-tau inversion recovery sequences (STIR), a three-dimensional (3D) T1 FLASH (fast low angle shot) sequence with fat saturation in the transverse and sagittal planes and a 3D T1 FISP (fast imaging with steady precession) sequence in the dorsal plane. It is helpful to place the affected limb down to enhance the image quality by minimizing motion and to use the contralateral limb for comparison. Using the opposite limb for comparison is essential to determine whether a suspicious signal in a structure is real or a normal anatomical variation. In addition, bilateral pathology can manifest at the same locations, which requires careful reading of the significance of some signal abnormalities.

The fetlock region is becoming a common site of MRI to help accurately diagnose the causes of lameness in sport horses in a variety of disciplines.3–8 The fetlock region becomes a candidate for an MRI when pain has been localized to the fetlock region using diagnostic analgesia but radiographic or ultrasonographic examination are unable to appreciate significant abnormalities sufficient to explain the degree of lameness.9 King et al10 reported on 232 horses with lameness localized to the fetlock region that were without a radiographic diagnosis. Soft-tissue abnormalities were observed in 218 limbs (162 horses). Subchondral bone (SCB) and articular cartilage abnormalities were observed in 43 limbs (34 horses). Oblique distal sesamoidean ligament desmitis was the primary abnormality observed in 73 limbs (56 horses). Straight distal sesamoidean ligament desmitis was the primary abnormality observed in 44 limbs (38 horses). In another retrospective study of 40 horses that had the fetlock evaluated with magnetic resonance (MR), it was found that the most common injury to be SCB abnormalities of the distal metacarpus. Cartilage and osteochondral lesions in the fetlock joint and injuries of the suspensory ligament branches and PSBs were less common but also occurred with regular frequency. Concurrent soft-tissue injuries were present in 63% (25/40) of horses with SCB injury, most commonly involving the suspensory apparatus.8 Both studies found that the most common soft-tissue injury was of the distal sesamoidean ligaments (DSL) although the prevalent DSL injury occurred in the straight sesamoidean ligament (SSL) in one study and the oblique sesamoidean ligament (OSL) in the other.3,8 Abnormalities of SCB and lesions of distal sesamoidean ligaments have also been frequently diagnosed in other reports.6,7,10 SCB injuries can be diagnosed with low-field MRI5 but there are currently no reports on distal sesamoidean ligament injuries diagnosed with low-field MRI.

2. SCB Abnormalities
Normal SCB thickness of the distal aspect of the third metacarpal/metatarsal bone and proximal phalanx can be quite variable and is likely to change with the type and intensity of exercise the horse performs. In general, the SCB thickness of the distal aspect of the third metacarpal bone varies from dorsal to palmar and from abaxial to axial, being thinnest axially and thickest in the middle of each condyle, especially toward the palmar aspect.9
The SCB thickness of the proximal phalanx increases slightly toward the palmar aspect of each condyle. There is reasonable symmetry in SCB thickness of both the third metacarpal bone and proximal phalanx.

Joint injury is often manifested in the SCB. SCB remodeling due to repetitive cyclic loading can lead to sclerosis, which can become painful, often without disruption of the articular cartilage. The most recognizable example of chronic SCB trauma in horses is seen in cases of nonadaptive bone remodeling, which develops osteosclerosis and osteonecrosis of the palmar metacarpal or metatarsal condyles in racehorses. More advanced cases of nonadaptive bone remodeling can develop focal osteonecrosis in the center of an area of sclerosis in the palmar/plantar condyles of the metacarpus/metatarsus. When located close to the articular surface, osteonecrosis may lead to secondary articular cartilage damage and loss. The MR signal changes associated with this condition are often seen as diffuse T1, PD, and T2 signal decrease consistent with trabecular thickening and osteosclerosis. Occasionally the changes progress to diffuse or focal increase in signal in fat-suppressed images as well.

SCB damage can also occur due to traumatic incidents with or without articular cartilage damage. A “bone bruise” is a well-recognized cause of joint pain in people and is identified using MRI. Acute traumatic injury can develop a fluid-like signal that appears in bone as diffuse or focal increase in signal in fat-suppressed images. Diffuse or focal increase in signal in fat-suppressed images is a descriptive term called bone edema or bruising. Microfractures in the trabecular bone can lead to hemorrhage and edema and are likely the source of the abnormal high-signal intensity. Often these acute injuries occur without sclerotic changes. When these injuries occur in sites of normal sclerotic change it may be difficult to stage the injury, making it unclear whether the presence of bone-edema signal is an indication of acute traumatic accumulation of inflammatory fluid, or whether it may occur as a consequence of chronic SCB remodeling and fibrosis with or without venous congestion. Occasionally, small osseous cyst-like lesions may manifest with trabecular necrosis demonstrated by a focal T1, PD, and T2 signal increase, often with a sclerotic rim of bone. Osteoarthritis with associated articular cartilage damage and/or loss can lead to increased low signal in SCB with related increased bone density. It was hoped that MRI would be a good imaging modality to determine the status of articular cartilage damage seen in osteoarthritis. Unfortunately, particularly with respect to the fetlock joint of the horse, this does not seem to be the case. Several studies have reported on the inaccuracy of MR imaging in the detection of cartilage lesions. Small cartilage defects can be difficult to detect in both people and in horses. The location of focal articular cartilage lesions are most often located in the medial condyle of the distal third metacarpal/metatarsal bone with a preference for the palmar/plantar aspect of the condyle. The dorsal aspect of the condyles can also be affected with traumatically induced focal cartilage defects most often seen in non-racehorses.

Several papers have described the presence of proximal phalanx fractures not demonstrated on radiographs but seen with MR. Although sagittal fractures of the proximal phalanx are seen primarily in racehorses, they are now being reported in sport horses. These fractures are usually nondisplaced and begin at the dorsoproximal joint surface, making it difficult to appreciate radiographically unless the radiographic beam angle is positioned appropriately. Diagnostic analgesia can effectively eliminate pain associated with this condition and allow normal weight bearing, which could lead to fracture propagation. Quite surprisingly, several reports of appropriately placed diagnostic analgesia at the level of the palmar digital and basi-sesamoid can effectively eliminate the pain associated with these types of fractures.

3. Distal Sesamoidean Ligament Injuries
As mentioned earlier, the most commonly diagnosed soft-tissue injury seen on MRI of the fetlock region is to the DSLs. Both of these studies reported difficulty in the use of diagnostic ultrasound to accurately diagnose these injuries. On MR examination, the straight distal sesamoidean ligament (SSL) has a heterogeneous appearance with multiple high- and low-signal areas spread throughout most of its length. A normal small homogenous triangular signal hyperintensity exists at the insertion of the SSL onto the middle phalanx in the proton density and/or T1 weighted sequences. The oblique distal sesamoidean ligaments (OSLs) have intermediate signal intensity due to fibrocartilage separating the collagen bundles at their proximal aspect and heterogeneous signal intensity throughout their entire length from origin to insertion. The lateral OSL is frequently larger and more hyperintense than the medial ligament. Because of the variation between individual horses, imaging both limbs is critical to identify variations in signal intensity as normal or abnormal. In standing MR examinations, images of the proximal third of the OSLs are susceptible to magic angle effect, especially medially. This effect results from the divergence of fibers within the proximal third of each OSL, and the tendency for the medial OSL to be at a more oblique angle to the vertical than the lateral OSL. Magic angle effect results in increased signal intensity in the ligaments, thereby confounding image interpretation. The heterogeneity of the DSLs varies between individual horses. Normal signal heterogeneity should not be confused with the presence of abnormal signal hyperintensity, which commonly covers a larger cross-sectional area in several consecutive
Lesions within the OSLs and SSLs can result in discrete or diffuse areas of signal hyperintensity within the body or along the edge of the affected ligament. One or multiple small core lesions with focal-signal increase may be observed in affected ligaments, extending from 5 to 30 mm in a proximodistal direction. Enlargement of a ligament may also occur with or without abnormal signal increase, but this finding is less consistent. Lesions may occur biaxially or bilaterally. King et al. found that 22 horses diagnosed with DSL injury, all blocked to an intrathecal analgesia of the DFTS. In addition, they also found that intra-articular anesthesia improved lameness in 11 of 19 horses with DSL desmitis near their origin on the base of the PSBs.

The location of lesions within the distal sesamoid ligaments and the distribution of lesions varies between studies. Straight sesamoidean ligament desmitis occurs more commonly in the distal part of the ligament, proximal to its insertion on the middle phalanx, although proximal lesions near the origin were most common in one study. Oblique sesamoidean desmitis can occur proximally or throughout the entire length of the ligament. Cruciate distal sesamoidean desmitis is very rare. Reports suggest that when DSL desmitis occurs it is frequently regarded as the primary cause of lameness, although another author considered lesions to be the sole cause of lameness in only 2 of 58 horses with evidence of desmitis. The majority of horses with OSL or SSL desmitis diagnosed with MRI do not have a palpable enlargement or ultrasonographic abnormalities.

King et al. reported that OSL injury was diagnosed more frequently in Western performance horses (34%) compared with hunter jumpers (29%), racehorses (27%), and dressage horses (21%). SSL injury was most commonly diagnosed in dressage horses (39%) compared with other disciplines (racing 16%, hunter-jumper 13%, Western performance 11%). In that study, SSL injury was more common in Warmbloods (WB; 27%), compared to Thoroughbreds (TB; 15%), and Quarter Horses (QH; 13%).

**4. Suspensory Ligament Branch Injuries**

Suspended ligament branch injuries often occur in sport horses, sometimes without palpable localizing clinical signs, although there may be accentuation of lameness after distal limb flexion. Desmitis of the medial and or lateral branches of the suspensory ligament (SL) in forelimbs and hind limbs is a relatively common injury in all types of sports horses. Usually only a single branch is affected in a single limb, although both branches may be affected, especially in hind limbs. With the distal quarter of the branch positioned subsynovially branch, desmitis cases can often improve to an intra-articular block of the fetlock joint.

Each branch inserts primarily onto the abaxial surface of the ipsilateral PSB, apices of the PSBs and proximal scutum; the similarities of signal intensity (hypointense) can make defining the two structures as separate difficult. The suspensory ligament branches are paired triangular structures of low signal intensity that flatten in a dorsopalmar direction and widen lateromedially as they move distally toward their insertion on the PSBs. The margins of the branches are sharply delineated. Close to the insertion, the branches become C-shaped on cross section and high intensity, linear dorsopalmar striations appear in the branches, possibly associated with adaptive fibrocartilagenous metaplasia at the insertion. A small hyperintense indentation may be present in the palmar border of the (normal suspensory) branch immediately proximal to its insertion.

Suspensory branch lesions are characterized by an intraligamentous focus of signal hyperintensity in PD, T2, and STIR images, usually near the palmar/plantar border of the affected branch, with or without enlargement of the branch. Enlargement and increased high signal intensity may only become evident when compared with the contralateral limb.

Pathology associated with distal suspensory ligament desmopathy can often continue onto its insertion to the PSB, which significantly increases risk of bone pathology. When there is an increase in the cross-sectional area of the ligament with desmopathy, there is often a statistically significant higher risk of PSB pathology, as seen with MRI.

**5. Injuries of the PSBs**

Abnormal MR signal in the PSBs includes osteosclerosis, STIR hyperintensity consistent with bone edema or contusion, and focal trabecular bone loss associated with osseous cyst-like lesions at the attachment site of ligaments. Hyperintense lesions associated with osteolysis may be found at the axial margin of the PSBs in association with intersesamoidean (ISL) desmitis. Osteophyte formation at the proximal and distal margins of the sesamoid bones may be present in association with osteoarthrosis of the fetlock joint.

**6. Articular Cartilage Abnormalities**

MRI carries the distinct advantage of being able to detect bone and cartilage abnormalities not visible on radiographs. However, the cartilage on the distal surface of the third metacarpal/metatarsal bone in the fetlock joint is very difficult to image due to the curved distal margin and due to the fact that the articular cartilage layer is very thin. This joint tests the limits of current MR systems and the capability of these systems to resolve fine detail. Volumetric averaging occurs making it difficult to identify abnormalities in this thin articular cartilage. Using thinner slice thicknesses and obtaining slices perpendicular to the articular surface can make it easier to identify cartilage defects. Proton density or T1-weighted images with fat suppression can be helpful in creating differences in signal in-
tensity between the articular cartilage and synovial fluid and SCB, making identification easier. Small osteochondral (OC) defects occur commonly on the medial condyle in horses of all types and occur more frequently in the forelimbs. Cartilage lesions may also occur as isolated focal injuries with localized cartilage loss and little evidence of osteoarthritis or as part of the disease complex of an osteoarthritic joint. Cartilage injury or degeneration that results in wear lines or erosions in the cartilage is usually identified by the focal accumulation of hyperintense joint fluid in cartilage defects on PD and STIR images. Focal, irregular islands of fluid hyperintensity associated with pooling of synovial fluid in a chondral defect can sometimes be recognized on transverse PD, T2, or STIR images that are located exactly parallel with and through the affected articular surface. Cartilage defects have been identified on all articular surfaces in the fetlock joint.8 MR imaging tends to underestimate the size and extent of cartilage loss in the fetlock joint compared with arthroscopic findings.8 King et al13 found few articular cartilage abnormalities that did not involve the SCB. Abnormalities observed were thinning of the articular cartilage with decreased signal intensity. However, there were 36 horses in which a SCB or cartilage injury and soft-tissue injury were concurrently diagnosed and the primary cause of the lameness could not be determined. SCB damage can occur alone without disruption of the articular cartilage by repetitive cyclic loading or by one-time, traumatic incidents. Increased low signal in SCB can be due to increased bone density as a result of osteoarthritis and loss of articular cartilage; this could be the cause of increased bone sclerosis observed in some of the horses. Osteophytes may be seen as contour changes of the proximal and distal articular margins of the sesamoid bones and the dorsoproximal, lateral, and medial margins of the proximal phalanx. However, osteophytes may be more easily recognized on radiographs due to the radiographic summation effect and the better radiographic contrast between cortical bone and soft-tissue attachments at the joint margins.

7. Osteochondral Fragmentation
Osteochondral defects are often the result of osteochondrosis or trauma. Osteochondral fragments from the dorsal eminences of proximal phalanx (dorsoproximal margin) and from the basilar margin of the PSBs may not be visible radiographically but may be recognized as focal, osseous hypointensities separated from parent bone on all sequences. Osseous fragments may be difficult to distinguish from end-on blood vessels near joint margins as both may appear hypointense on MRI. Sagittal FLASH and PD images are most helpful in identifying these fragments. Fragments that occur within or around the attachment of the suspensory or distal sesamoidean ligaments to bone can be difficult to discern as they are both hypointense. Large OC defects occur most commonly around proximal P1 and the medial condyle. Small OC defects occurred most commonly on the medial condyle and were seen in all types of horses. OC defects as a group were diagnosed more frequently in the forelimbs.

8. Abnormalities of the Digital Flexor Tendons and Associated Sheath
Injuries to the superficial flexor tendon (SDFT) and deep digital flexor tendon (DDFT) in the DFTS may be recognized as dispersed small, focal areas of signal hyperintensity, distinct hyperintense core lesions, thickening of the affected lobe(s) and/or longitudinal parasagittal splits of the lateral or medial border of the tendon with partial separation of the tendon margin. Lesions of the SDFT within the DFTS may also extend distally into one of the branches of the tendon into its insertion. In the King study,3 SDF tendonitis was diagnosed in 10 limbs (nine horses) and involved the manica flexoria in six limbs (five horses). Abnormalities in the manica flexoria appeared as thickening with diffuse increased high signal intensity and often with overt tears. DDFT injuries are often visualized as enlarged with diffuse areas of increased high signal intensity, and core lesion. Lesions of the DDFT within the DFTS may continue distally into the navicular bursa and insertion onto the distal phalanx. Hyperintensities and contour changes of the flexor tendons within the DFTS are most obvious in transverse FLASH (gradient echo) images and frequently not visible ultrasonographically. Flexor tendon abnormalities seem to be uncommon in the reports of MR evaluation of the fetlock probably because these injuries are frequently seen with diagnostic ultrasound and addressed without the need for MR evaluation.

9. Other Abnormalities
Other injuries have been reported in the fetlock region with a lower incidence than those listed above, including desmitis of the intersesamoidean ligament (ISL) and CL.8 Intersesamoidean desmitis results in a large or small, focal, central area of hyperintensity within the ISL in T2, PD, and STIR images. Extension of the inflammatory change that extends into the axial surfaces of the PSBs is considered axial osteitis. This osteolysis is represented as an area of intraosseous hyperintensity confluent with the area of signal increase in the ISL. MR imaging proves helpful to define the extent of the osteolysis and determine whether the fetlock joint or the DFTS is/are involved. Increased fluid distension and intrathecal soft tissue proliferation of the DFTS may occur with associated change in the palmar annular ligament (PAL).

Primary PAL abnormalities unrelated to ISL desmitis and axial osteitis can be seen as thickening of the ligament. Primary PAL abnormalities can be seen as thickening of the ligament and mildly increased high signal intensity. Flexor tendinitis

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can occur in association with or due to abnormalities of the PAL. In addition, insertional injuries to the PSBs do occur as isolated injuries and often have abnormal high signal intensity visualized on fat-suppressed images. Other soft-tissue injuries can be seen infrequently. They included thickening of the fibrocartilage pad and dorsal joint capsule thickening or tearing increased high signal intensity.

CL desmitis does occur and is characterized by enlargement of the superficial or deep part of the CL relative to the contralateral limb and by the presence of hyperintensity in T2 and PD images in the affected part of the ligament. Signal increase may be difficult to recognize in the deep part of the collateral ligament as this structure is frequently obscured on MR images by the presence of magic angle effect when the leg is aligned with the central axis of a high field magnet. Evidence of endosteal response may be present as an irregularity at the origin of a collateral ligament. A small avulsion fragment at the base of the epicondylar fossa in association with CL desmitis has been described. In one study, lameness due to CL injury improved three of three horses with intra-articular fetlock anesthesia.

Short incomplete sagittal P1 fractures have been found on MR when radiographs were negative. In one study of TB racehorses with pain originating from the fetlock region examined with standing MR, it was found that 19/131 (14.5%) horses were diagnosed with short incomplete sagittal plane fractures of P1. Five hind limbs and 14 forelimbs were affected. Focal linear hyperintensity was seen on all sequences within the cortical SCB of the dorsal articular margin of P1 in 16/19 (84.2%) of cases surrounded by marked bone remodeling (BMO-type signal) (STIR and T2* hyperintensity/T1 hypointensity).

Conclusion

The main advantage of using MRI to evaluate the lameness felt to originate in the fetlock region is accurate definition of the specific cause(s) of lameness. As many of these injuries are not often apparent with conventional imaging tools (radiographic and ultrasonographic examination) it may be that MRI is the only imaging tool capable of demonstrating the injury(s). Treatment obviously should be chosen based on the specific injury(s) and can be modified based on the specific structure, the site and severity of injury, and the suspected duration of the injury. This is often heavily influenced by clinician preference/experience. Discussion of specific injuries and their treatments will be addressed during the presentation.

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MRI in the Diagnosis of Foot Lameness and Therapeutic Approaches Following an Accurate MRI Diagnosis

Chad Marsh, DVM, MS, DACVS

1. Introduction
Navicular syndrome, or palmar foot pain, continues to be one of the most common causes of forelimb lameness in many types of athletic horses. Definitive diagnosis in the past has been difficult and primarily based on clinical signs, response to diagnostic local anesthesia, radiographic findings, nuclear scintigraphy, in some cases ultrasound, and response to treatment. Experience with magnetic resonance imaging (MRI) during the last 13 years has improved the diagnosis of bone and soft tissue injuries within the feet of horses with navicular syndrome. MRI has become a valuable diagnostic tool that allows recognition of many abnormalities in horses previously grouped into a single clinical diagnosis. Pathology in numerous structures within the foot can cause clinical signs of navicular syndrome, including the navicular bone, distal sesamoidean impar ligament (DSIL), collateral sesamoidean ligament (CSL), navicular bursa, deep digital flexor tendon (DDFT), collateral ligaments of the distal or proximal interphalangeal joint, distal digital annular ligament (DDAL), distal phalanx, straight and oblique sesamoidean ligaments, middle phalanx, or laminae. Abnormalities in any of these structures have the potential to cause pain, which is alleviated by injection of local anesthetic around the palmar digital nerves (PDNs). With the myriad of different pathologic problems that can be present within the foot, treatment can vary greatly depending upon the duration of the problem and the location of the pathologic change.

The purpose of this paper is to identify the usefulness of MRI in making an accurate diagnosis of lameness that has been localized to the foot and highlight common pathologic problems within the foot and anatomical structures that can often go undiagnosed with conventional diagnostic modalities. In addition, therapeutic approaches and prognosis, when a diagnosis is determined, will be discussed.

Foot Pain
In cases in which lameness is abolished by a palmar digital nerve block (PDNB), a common misconception is that pathology is isolated to the palmar/plantar structures of the foot (i.e. DDFT, navicular bone, navicular bursa, DSIL, and CSL). Although this is true in many cases, there is also a propensity for a routine PDNB to alleviate pain associated with
numerous other structures in close proximity (i.e. straight and oblique sesamoidean ligament, pastern joint, coffin joint, middle and distal phalanx, and in some cases the fetlock joint). As equine veterinarians become more aware of the number of abnormalities that can be present within the foot and surrounding structures, we continually strive to become more specific with our blocking patterns. However, even with the addition of more specific blocks (coffin joint, tendon sheath, navicular bursa, unilateral PDNs), it is often difficult or impossible to isolate the cause of lameness to a single structure, given that multiple structures can be and are commonly affected.

2. Specific Pathologic Abnormalties

Bone Abnormalities

Bone Edema
Bone edema is a common term that is used in advanced diagnostic imaging and can be misleading. “Bone edema” is simply an abnormal increase in signal on any fat-saturated sequence (Fig. 1). The term implies that if edema is present, inflammation is also present. Although this is sometimes true, this increase in signal can also suggest many pathologic processes that are not inflammatory in nature such as hemorrhage, necrosis/osteonecrosis, or fibrosis. Based on personal experience, by far the most common location of bone edema within the foot is the navicular bone. In addition to the navicular bone, other common locations for bone edema include P2 (predominately distal P2) and P3. Although many horses can have some minor osseous changes such as periarticular remodeling/navicular bone degeneration, specific sites of bone edema are not apparent radiographically, making definitive diagnosis only possible with MRI.

Navicular Bone Degeneration
The severity of navicular bone degeneration is sometimes quite difficult to predict based on radiographic studies alone (Fig. 2). It is well documented that radiographic changes, or the lack of radiographic abnormalities of the navicular bone do not always correlate with clinical lameness. Palmar cortical erosions, damage to the palmar fibrocartilage of the navicular bone, navicular bone cyst, navicular bone edema, and distal navicular bone corner fragments of the navicular bone are easily diagnosed with MRI but can commonly be overlooked on radiographic studies.

Subchondral Bone and Cartilage Injuries
Multiple abnormalities of the subchondral bone and cartilage can be identified with MRI (Fig. 3). The ability to detect cartilage abnormalities can be highly dependent on the field strength of the magnet. Low-field magnets are much less likely to detect early partial thickness cartilage injuries and some full-thickness abnormalities. In contrast, high-field magnets allow for a more detailed evaluation of the articular cartilage. Early partial thickness and more severe full-thickness cartilage lesions can be identified within the distal interphalangeal and proximal interphalangeal joints. Subchondral bone abnormalities that can be identified include sclerosis, cysts, edema, and microfractures.
Soft-Tissue Abnormalities

Deep Digital Flexor Tendonitis/Tendonopathy

Injuries of the DDFT are common and can occur in single or multiple locations within the foot (Fig. 4). Severity, location, and type of lesions are critical to determine the most appropriate treatment option and prognosis. The type of damage to the DDFT can be manifested in many ways, including sagittal splits, core lesions, dorsal fibrillation, diffuse disease, and generalized enlargement. Based on clinical impression, a common location for tendinosis/tendonitis is at the proximal recess of the navicular bursa, with or without extension proximal into the digital flexor tendon sheath. In addition, sagittal splits at the level of the navicular bone, insertional injuries at the attachment of the DDFT onto the palmar/plantar solar margin of the coffin bone, and significant extension of tendonitis into the digital flexor tendon sheath are also common locations of damage.

The severity/chronicity of lesions is largely based on the signal intensity. It is largely accepted that lesions with high signal intensity on proton density images are more severe. The images in Fig. 2 and Fig. 3 illustrate these findings.

Fig. 2. Degeneration of the navicular bone. Sagittal proton density image of the foot (A) showing sclerosis (green arrow) and a palmar flexor cortical erosion (red arrow) and gradient echo transverse image of the foot (B) showing a palmar flexor cortical erosion (red arrow).

Fig. 3. Subchondral bone/cartilage abnormality. Dorsal gradient echo image of the foot (A) showing a subchondral cyst in the distal phalanx (red arrow) and dorsal proton density image of the foot (B) shoeing an articular cartilage and subchondral bone injury within the pastern (red arrows).
density/T1-weighted sequences and low signal intensity on T2 and fat-suppressed images are less severe or more chronic in nature. In addition, it has also been shown that very early tendinosis can be manifested as increased signal intensity seen only on T1 and gradient echo sequences. It has been shown that in chronic cases of tendonitis, high signal intensity on T1-weighted images were areas of fibrosis/fibroplasias in contrast with lesions with high signal intensity on all sequences, which were more active/severe lesions with necrotic changes.

Supporting Ligaments of the Navicular Bone

MRI provides the best means of evaluation of the supporting ligaments of the navicular bone, the CSL, and DSIL (Fig. 5). These supporting ligaments are commonly injured within the foot. A definitive diagnosis of CSL and DSIL desmitis is difficult with radiographic or ultrasonographic examinations alone due to the location deep within the hoof capsule. MRI appearance in desmitis of the CSL is manifested by enlargement and increased signal intensity in acute cases or low signal intensity due to fibrosis in more chronic cases. Many times this is accompanied by radiographic evidence of enthesopathy present on the medial and lateral proximal wings of the navicular bone. Impar ligament desmitis is also characterized by enlargement and increased signal intensity on the MRI. In addition to enlargement many cases have tissue of intermediate signal intensity between the impar ligament and the DDFT suggesting the presence of adhesions between the ligament and the DDFT. Avulsion/marginal fragments at the origin of the impar ligament on the distal border of the navicular bone, and insertional bone edema/cysts of the coffin bone can also be present.

Collateral Ligament Desmitis

Injuries to the collateral ligament of the distal interphalangeal joint are best evaluated with MRI.
Lesions of the collateral ligament are distinguished by enlargement and increased signal intensity of the ligament. A portion (proximal aspect) of the ligament can be evaluated ultrasonographically; however, a majority of the ligament is confined within the hoof capsule making diagnosis of more distal abnormalities challenging. Cystic lesion within the third phalanx at the insertion of the collateral ligament (collateral fossae) can occur and are characterized by increased signal intensity on all sequences.

**Distal Straight and Oblique Sesamoidean Ligament Desmitis**

Injuries to the straight and oblique sesamoidean ligaments are often overlooked following improve-
ment of lameness with a PDNB (Fig. 7). With possible proximal diffusion of local anesthetic, it is possible to block out lameness due to injuries of the sesamoidean ligaments. Because of the propensity to block lesions more proximal than the foot, it is imperative to obtain limited MRI sequences more proximal to include the sesamoidean ligaments, given that they are often not obtained during a routine MRI examination of the foot. Lesions of the sesamoidean ligaments are characterized by enlargement and focal or diffuse areas of increased signal intensity within the ligament. Interpretation of abnormalities of the oblique sesamoidean ligaments is often difficult due to the variability in size and signal intensity of subclinical or normal sesamoidean ligaments. It is essential to have comparative images of the contralateral sesamoidean ligaments to aid in determining the significance of abnormalities noted on the MRI.

Navicular Bursitis
Navicular bursitis can include simple increased fluid present within the navicular bursa or severe thickening of the bursa with scar tissue and adhesion formation (Fig. 8). Effusion present within the navicular bursa is characterized by an increased amount of hyperintense synovial fluid present within the proximal and distal recess of the bursa. The exact cause of the increase in fluid is unknown; however, in many cases there is concurrent navicular bone edema. In most cases, effusion is easily manageable and can be transient. In contrast, proliferative bursitis seems to occur in more chronic cases of navicular bursitis. It is speculated that persistent inflammation of the bursa causes proliferation of tissue of intermediate signal intensity and thickening of the bursal wall leading to the development of adhesions and proliferative synovium within the proximal and distal recess of the bursa. Proliferative bursitis is more difficult to manage and sometimes requires more aggressive treatment.

Laminar Abnormalities
MRI provides excellent detail regarding the sensitive and insensitive lamina of the foot (Fig. 9). This allows the early diagnosis and intervention of keratomas, acute laminitis, laminar separation, helping to prevent progression of disease.

Therapeutic Approaches Following and Accurate MRI Diagnosis

**Deep Digital Flexor Tendonitis/Tendonopathy**
Injuries to the DDFT within the foot are one of the most common pathologic conditions diagnosed with MRI. As discussed previously, there are many factors to consider when determining appropriate treatment regimens for injuries of the DDFT. Major factors that determine treatment and prognosis include duration (acute vs chronic), type (core lesions, diffuse disease, and sagittal splits), location, and severity of injury to the DDFT. In addition to treatments described below, the primary treatment recommendation for many soft-tissue injuries is a rest and rehabilitation program to allow time for the tendon or ligament to heal, in addition to a recommended therapeutic shoeing protocol.

**Biologic Therapies**
Recently, the use of biologics in the treatment of tendon and ligament injuries has become well accepted and very popular. Currently, the most pop-
ular biologic treatment options include bone marrow–derived mesenchymal stem cells (BM-MSC), platelet-rich plasma, and autologous conditioned serum. It is generally accepted that biologic treatments are typically administered by direct intralesional injection, local regional limb perfusion, or a combination of the two methods. Although these methods are widely accepted and used in treatment of equine musculoskeletal injuries, there are still many unanswered questions about their mechanism of action, duration of action, and efficacy.

Acute core lesions present within the DDFT can be treated by direct injection of biologics under ultrasonographic guidance. Direct intralesional injection relies on the ability to observe the lesions under ultrasonographic guidance, but are somewhat limited to locations proximal to the navicular bursa. As lesions progress more distal within the foot, direct injection becomes more difficult. Guided placement of needles into acute core lesions is reported under computed tomography (CT) guidance. Radiographic guidance is also reported; however, certainty that the biologic is administered directly into the lesion is questionable. In cases of direct communication with synovial structures, biologics can be administered via synovial injections.

In diffuse injuries to tendons or ligaments and lesions located distal to the navicular bursa, regional limb perfusions of BM-MSCs are gaining popularity. This relies on the BM-MSCs ability to home to areas of active inflammation or injury. In addition to the use of biologics, other medical and surgical treatments are described below for the treatment of soft-tissue injuries within the foot.

**Collateral Ligament Desmitis of the Distal Interphalangeal Joint**

There are a wide range of treatment options for collateral ligament injuries. The primary treatment recommendation for collateral ligament injuries is a rest and rehabilitation program to allow time for the ligaments to heal. Additional thera-
pies include direct injection of biologics into the affected ligament, and the recommendation of an appropriate therapeutic shoeing protocol. Direct injection of the entire collateral ligament is typically performed under radiographic guidance. Osseous abnormalities at the origin and insertion of the collateral ligament are common. Development of cysts at the origin and insertion of the collateral ligaments may require additional surgical therapies. Invasion and curettage of the cyst contents can be performed under radiographic or fluoroscopic guidance.

Navicular Bursoscopy

Endoscopy of the navicular bursa can be a valuable diagnostic and treatment tool in pathologic conditions of the navicular bursa following an MRI diagnosis. There are two surgical approaches to the navicular bursa in the horse. Surgical approaches for navicular bursoscopy include a direct approach and a transthecal approach in which the bursa is entered through the tendon sheath following resection of the T-ligament. The author prefers the transthecal approach unless there is suspected or confirmed sepsis of the navicular bursa. The transthecal approach to the navicular bursa allows thorough examination of the digital flexor tendon sheath and in many cases can aid in tenoscopic guided injection of biologics at the time of surgery. In cases of septic navicular bursitis the direct approach is preferred to prevent contamination of other closely associated synovial structures. Treatment of septic navicular bursitis via navicular bursoscopy includes resection of proliferative synovium, copious lavage, local and systemic antibiotics, and in some cases development of distal drainage if the bursa was invaded through a tract in the frog or solar surface of the foot.

Non-septic pathologic conditions that are commonly treated with navicular bursoscopy include sagittal splits within the DDFT at the level of the navicular bone, dorsal margin abrasions/tearing/fraying of the DDFT at the proximal recess of the navicular bursa, scar tissue/adhesion formation between the DDFT and navicular bursa, adhesions from the navicular bone to the DDFT, recurrent navicular bursitis, and erosive lesions on the palmar/plantar surface of the navicular bone. A majority of conditions treated within the navicular bursa are associated with injuries to the soft tissues in close association to the navicular bursa. Injuries to these soft tissue structures require resection or debridement of the affected tissue. In some cases, there is subsequent damage to the palmar/plantar fibrocartilage of the navicular bone that requires debridement. The rationale for debridement of lesions within the navicular bursa is based on clinical observations that tendon injuries with synovial communication do not heal well. The inability of the DDFT to heal is likely multifactorial. Ingress of synovial fluid has the potential to decrease the ability to create a scar of the affected area thereby decreasing the ability to contain the intrinsic cofactors required to promote healing. In addition, the proportion of exposed disrupted collagen within a synovial cavity can causes persistent inflammation and lameness that has a direct correlation with the severity of synovitis present within the navicular bursa. In addition, tendons confined within a synovial structure rely heavily on intrinsic healing. Debridement of these damaged fibers is thought to stimulate the intrinsic healing mechanism. A recent study reports favorable outcomes following bursoscopy for the treatment of numerous pathologic conditions of the navicular bursa. In this report of 114 horses, 63% of horses that underwent navicular bursoscopy were sound and in work and 37% of these horses were performing at a level of equal or greater than that achieved before surgery. Horses in the study with extensive tearing of the DDFT and combined injuries to the navicular bone and DDFT were less likely to be sound compared with horses with only small tears of the DDFT. Outcomes following surgical debridement of tendon lesions compares favorably to medical management alone reported in other studies.

Tenoscopy of the Digital Flexor Tendon Sheath

Injuries of soft tissue structures confined within the digital flexor tendon sheath (DFTS) are commonly diagnosed with MRI following resolution of lameness with a PDNB. Tendonitis and desmitis of the DDFT, SDFT, sesamoidean ligaments, and DDAL are common injuries within the DFTS. Restrictive scar-tissue adhesions spanning from the tendons to the tendon sheath are also common findings. Tenoscopy is indicated in cases in which there is proliferative tissue within the DFTS, adhesion formation between the tendons and tendon sheath, or when there is significant enlargement of the DDAL that requires desmotomy. At the time of tenoscopic evaluation if there is concurrent tendonitis/desmitis, tenoscopic-guided injections of biologics can be performed.

Coffin Joint Arthroscopy

Pathologic conditions that warrant arthroscopy of the coffin joint are limited to subchondral bone, articular cartilage abnormalities, and surgical transaction of the CSL of the navicular bone. Common lesions debrided arthroscopically are subchondral cysts and articular cartilage lesions located within a reasonable distance from the extensor process to allow adequate accessibility. When surgical debridement is not possible, medical management with intrasynovial therapies are the treatment of choice. Options for medical management include autologous conditioned serum, BM-MSCs, and corticosteroids. In addition, enlargement of the CSL of the navicular bone is a common MRI diagnosis. When CSL desmitis is the sole abnormality noted, horses are placed in rest and a rehabilitation pro-
gram to allow time for the ligament to heal. If resolution of the CSL does not occur, arthroscopic transaction of the ligament is warranted.33

**Navicular Bursa Injections**

Previously, injection of the navicular bursa with corticosteroids and hyaluronic acid had been reserved for cases of lameness that did not respond to therapeutic shoeing, administration of NSAIDs, or injections of corticosteroids in the distal interphalangeal joint. More recently, navicular bursa injections have become a first line of medical treatment after MRI has revealed a pathologic change in the bursa or within close proximity. Medical management of the navicular bursa can be used to continue horses in work or to reduce the inflammation associated with acute pathologic changes followed by placement of horses into a rest and rehabilitation program. Currently, the author’s approach to treatment of horses with pathology localized to the navicular bursa region is highly dependent on the lesion present.

1. Horses with acute core lesions present within the proximal navicular bursa, over the palmar/plantar aspect of the navicular bone, and insertional core DDFT injuries: If there is no communication of the tendon lesion with the navicular bursa the author will perform navicular bursa injections with corticosteroids (methylprednisolone acetate) and hyaluronic acid. Following injections, the horses are shod with therapeutic shoes and placed in a rest and rehabilitation program to allow time for the tendon to heal.

2. Horses with sagittal splits of the DDFT or tears that communicate with synovial fluid: Most sagittal splits within the tendon have a communication with the bursa that allows ingress of synovial fluid into the tendon injury. One approach to treatment is injection of BM-MSCs directly into the navicular bursa. The second approach to treatment is intrabursal injection of corticosteroids (triamcinolone acetonide) and hyaluronic acid. Following injections, the horses are shod with therapeutic shoes and placed in a rest and rehabilitation program.

3. Horses with scar tissue/adhesions within the proximal recess of the navicular bursa. The author prefers triamcinolone acetonide when there is a direct communication of synovial fluid and tendon tissue as there are some potential deleterious effects of certain corticosteroids within the tendon tissue.

4. Horses with navicular bursitis (effusive only): Horses with fluid-filled navicular bursitis are often managed by radiographic-guided navicular bursa injections of cortisone and hyaluronic acid. Effusive bursitis can sometimes resolve with a one-time injection; however, some horses continually develop bursitis that requires repeated injections. Some horses that require frequent injections warrant navicular bursoscopy and resection of the T-ligament so that a direct communication between the tendon sheath and navicular bursa is obtained. Development of a direct communication allows treatment (less invasive than continued navicular bursa injections) of the tendon sheath and subsequent treatment of the bursa due to the established communication.

5. Horses with multiple abnormalities (i.e., flexor cortical erosions and concurrent soft tissue injuries within the DDFT): In most cases these horses are treated with intrabursal injections of corticosteroids and hyaluronic acid. Many times these horses are continued in work unless there is evidence of an acute soft tissue injury that would require a rest-and-rehabilitation program.

A recent study evaluating the efficacy of navicular bursa injections in horses with navicular syndrome demonstrated that response was highly dependent on the disease process detected on MRI and the duration of lameness. In this study, 70% of horses with deep digital flexor (DDF) tendonitis were able to return to their intended use for a mean of 14 months and 50% were still sound at the time of follow-up. This compares favorably to other studies in which return to soundness in DDF tendonitis ranges from 20 to 75%; however, in the current study a large portion of horses were diagnosed with acute tendonitis. Horses with chronic soft-tissue injuries (>6 mo) or multiple abnormalities had a variable and poorer prognosis than horses with acute injuries.34

**Intrathecal Injections of the Digital Flexor Tendon Sheath**

Injections of the digital flexor tendon sheath can be performed for diagnostic and therapeutic purposes. There are relatively few structures confined within the digital flexor tendon sheath (DDFT, SDFT, portions of the straight and oblique sesamoidean ligaments, and DDAL). In many cases of lameness localized to the foot there are multiple soft tissue injuries present on the MRI examination. The difficult question is which pathologic abnormality is contributing most to the current lameness? Local intrathecal anesthesia of the DFTS can be used if there is suspected pathology that is confined within the sheath. Injection of local anesthesia into the DFTS will improve lameness associated with injuries of the DDFT, SDFT, sesamoidean ligaments,
and DDAL. If the horse responds favorably to local anesthesia of the DFTS, medical or surgical therapy of the sheath is indicated. Therapy can consist of direct intralesional injection with biologics into the tendon or ligament affected or injection of cortisone and hyaluronic into the DFTS. As indicated above in treatment of DDFT injuries most injuries to the soft-tissue structures within the DFTS also require a rest-and-rehabilitation program to allow time for the tendon or ligament to heal. In some instances, restrictive scar tissue adhesions or enlargement of the DDAL can be a source of lameness in the sheath that can require tenoscopy for resection of adhesions or release of the DDAL.

**Distal Interphalangeal Joint Injections**

Intra-articular injections of the distal interphalangeal joint are commonly performed in the treatment of lameness localized to the foot. In many cases, MRI is able to identify abnormalities of the cartilage or underlying subchondral bone within the distal and proximal interphalangeal joint that are surgically inaccessible. In these cases, injection of corticosteroids or biologics can be performed to ameliorate lameness and continue horses in work. Prognosis is highly variable depending on the severity and location of the underlying pathology. For treatment of navicular bone edema, a routine coffin-joint injection with corticosteroids and a period of rest (~60–90 d) is often all that is needed for complete resolution of bone edema.

**Palmar/Plantar Digital Neurectomy**

Palmar/plantar digital neurectomies have been a mainstay in treatment of foot pain that is nonresponsive to conventional therapies. Prognosis and efficacy following neurectomies has been highly variable. Much of this variability is likely due to the inability to effectively determine pathology within the foot prior to performing the procedure. MRI can help to better determine good candidates for the procedure. Horses with severe injury to the soft tissues within the foot (DDFT, collateral ligament) and erosions on the flexor cortical surface of the navicular bone are poor candidates for surgery. Typically, if there is significant injury to the soft tissues within the foot, horses are placed in an extended rest-and-rehabilitation program prior to considering neurectomy as a surgical option. If horses with severe soft-tissue damage are allowed the appropriate amount of time to heal there is likely less chance for catastrophic injury if a neurectomy is performed in the future. In contrast, some horses with mild pathology of the navicular bone that is nonresponsive to medical treatments can have a positive outcome following neurectomy.

3. Conclusion

With the advent of MRI, it is evident that horses that were once classified into a single clinical diagnosis can have very different pathologic conditions within the foot. Medical and operating approaches to foot-related lameness vary greatly depending on structures affected within the complex anatomy of the foot. The ability to target treatments based on an accurate MRI diagnosis will continue to allow veterinarians to develop a more accurate prognosis and outcome.

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**Declaration of Ethics**

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**References**


How to Interpret Endocrine Diagnostics for the Sub-Fertile Mare

Alejandro Esteller-Vico, DVM, PhD

1. Introduction
Endocrine diagnostic tests are useful for evaluating many reproductive conditions in the mare. Whether considering either an open mare or a pregnant mare, a number of hormones can be used to evaluate overall reproductive health or wellbeing of a pregnancy. Although some of these tests have been in use for many decades and others were recently developed, there are still a number of tests that are being developed and have great potential as diagnostic markers. Endocrinology has the obvious advantage of aiding diagnoses without requiring expensive equipment or spending too much time. All that is necessary to obtain an endocrine diagnosis is to collect a blood sample and send it to one of many clinical laboratories along with a brief history for the case. Some of these tests will provide a definitive diagnosis, but some tests will be inconclusive and therefore in frustration for veterinarians and their clients. However, such tests are sometimes inconclusive because they were not appropriately selected or because the blood sample was collected outside of the appropriate timeframe for that test. The scope of this paper is to describe which tests are adequate for each condition and when those tests are useful for evaluating the reproductive health of the mare.

The discussion will also include some aspects of the main laboratory techniques used to measure these reproductive hormones, their limitations, and the directions clinical endocrinology will be moving in the near future. Subfertility in the mare is a multifactorial disease and is often defined as a mare that does not conceive easily or that has trouble carrying foals to term. However, there is often a fine line between fertile and subfertile mares and between subfertile and infertile mares. A number of conditions or circumstances associated with subfertility are related to the age of the mare, to abnormalities of the anatomy in their reproductive tract, or to mares prone to uterine infections and in some cases to specific hormonal imbalances or deficiencies. Often, a number of these conditions will overlap and it will be difficult or nearly impossible to elucidate the primary cause for the reproductive failure. There is an intrinsic difficulty when assessing a subfertile mare, given that these mares are usually affected by a number of different conditions and do not have consistent endocrine profiles. However, endocrine profiles are well characterized in the fertile mare and can be used when evaluating a subfertile mare.
2. Progestogens

Progestogens are a class of steroid hormones that are synthesized by the corpus luteum (CL) during the luteal phase and early stages of pregnancy, and by the fetoplacental unit during mid and late gestation. The role of progestogens, also known as progestagens, is to switch the luminal and glandular epithelium from a proliferative state to a secretory state, and to maintain uterine quiescence; in other words, to help sustain and nourish the embryo or fetus. There are at least 10 known progestogens present in maternal circulation at some point during gestation with the potential for even more. However, to date only a few of them are known to be bioactive: these are progesterone (P4), 5α-dihydroprogesterone (5α-DHP), and to some extent allopregnanolone. Other progestogens might also be bioactive or might simply be metabolites present in circulation.

Progesterone is the most renowned and studied of this class of steroid hormones. Progesterone concentration in the mare starts to increase immediately after ovulation and is produced by the primary CL. If there is an embryo present in the uterus and maternal recognition of pregnancy occurs, the life span of that CL will extend beyond the normal length of diestrus and P4 concentrations will remain elevated. During early pregnancy, there will be a second increase in P4 concentrations, which is associated with equine chorionic gonadotropin. This gonadotropin is first detectable in circulation at approximately days 35–40 of gestation and has a double effect in the P4 profile: first through direct luteotrophic stimulation of the primary CL, and second through the formation of secondary corpora lutea. Due to this second increase in P4, circulating levels continue to increase, peaking between days 60 and 120 of gestation. From that point on, P4 slowly decreases until being nearly undetectable at approximately days 180 to 200 days of gestation.

Other progestogens are simultaneously produced by the fetoplacental unit and are first detectable by day 60 of gestation. The sole production of progestogens by the fetoplacental units is completely capable of maintaining pregnancy at approximately days 120 to 140 of gestation, as shown through ovarioectomy studies.

From a diagnostic perspective, circulating P4 has been used to evaluate luteal function during early pregnancy. In the literature, when circulating P4 is greater than 1 ng/mL, it is considered consistent with the presence of luteal tissue, indicating that a preovulatory follicle has ovulated, luteinized, and is producing P4. When circulating levels are greater than 4 ng/mL, they are considered adequate for the maintenance and support of pregnancy; however, this level may vary depending on the reference ranges used by the clinical laboratory where P4 was assayed. There are few reports in the literature or in anecdotal cases of mares suffering primarily from luteal insufficiency. However, there are other reasons for monitoring and supplementing endogenous P4 with progestins (synthetic form of P4) during pregnancy, such as mares suspect of compromised pregnancies due to uterine infections, previous history of pregnancy loss, inadvertent administration of prostaglandins, and a number of other clinical reasons. During late gestation, there are also a number of reasons to supplement endogenous progestogens; however, monitoring based upon current standard immunoassays does not provide useful clinical information due to lack of specificity in the laboratory techniques.

There are a few important issues regarding laboratory techniques and progestogens that require clarification. To date, all clinical veterinary diagnostic laboratories use immunoassays to measure circulating progesterone. Whether radio-immunoassays or enzyme-immunoassays, the specificity of these tests is limited by the antibodies used in these assays. Their specificity depends on the antigen or epitope with which the antibody is designed to immunoreact. Therefore, if that epitope or antigen is present in other molecules, that antibody is unable to differentiate between those molecules and will give false or inaccurate results. When it comes to late gestation in the mare, there is a great variety of progestogens circulating in large quantities, which makes immunoassays unreliable to evaluate any of them. In addition to this lack of specificity, different antibodies will result in disparate amounts of cross reactivity; therefore, each P4 assay will measure different amounts of progestogens, producing distinct results. It is important to emphasize that best clinical interpretation for any P4 result is the one provided by the clinical laboratory that measured that P4, given that they should have normal reference ranges for that specific assay.

The specificity lacking in immunoassays and the inter-laboratory variations can be overcome with the use of the much more specific liquid chromatography–mass spectrometry (LC-MS). Using LC-MS, researchers have been able to evaluate changes in different progestogens during late gestation, and there are current efforts to elucidate links between placental compromise during late gestation and the changes associated with specific progestogens. It would be advantageous for clinical laboratories to switch to LC-MS to provide diagnostic panels that would yield greater specificity and a wider array of progestogens evaluated.

In summary, current tests for P4 in the mare are useful to evaluate the presence of luteal tissue (P4 > 1 ng/mL) and to ensure that levels of circulating P4 are adequate for maintenance of early pregnancy (P4 > 4 ng/mL) until approximately 120 days of gestation.

3. Estrogens

Estrogens are also a useful diagnostic aid to evaluate reproductive status of the mare. Similar to pro-
gestogens, estrogens are a class of steroids that are synthesized by the ovary and the fetoplacental unit by aromatization of androgens. Among estrogens, the most well-renowned and studied is 17β-estradiol, which is key in the regulation of hypothalamic-pituitary-gonadal axis and in driving behavioral and reproductive aspects during estrus. There are also other estrogens, such as estrone, the B-ring unsaturated estrogens (equilin and equilenin), and the sulfconjugated metabolites that are present in circulation during different stages of pregnancy in the mare.14

As with progestogens, the current standard laboratory techniques used to measure circulating levels of estrogens are also immunoassays. Therefore, all of the precautions previously described for progestogens should be still taken into consideration. There are nevertheless several circumstances in which estrogens are useful diagnostic tools. To briefly summarize estrogen physiology, estradiol peaks during estrus. Estradiol is synthesized in the ovaries by large follicles and peaks in circulation during estrus, having a positive feedback effect on the hypothalamic-pituitary-gonadal axis that leads to an increase of luteinizing hormone (LH) and ultimately to ovulation. During this phase, estradiol also drives an important behavioral component, usually described as estrus behavior. It is noteworthy that this well-described “peak” of estradiol during estrus actually represents a very small quantitative increase of short duration. Therefore, even though control studies are able to differentiate between estrus and diestrus concentrations with daily samples, it is in most cases difficult to determine the phase of the estrous cycle in non-pregnant mares using estradiol in a clinical setting.

Currently, the best diagnostic use of estrogens in equine reproduction is that of estrone sulfate (ES) during pregnancy. There is a measurable increase in ES synthesized by the CL15 and associated with the increase in equine chorionic gonadotropin that occurs at approximately days 35–40 of gestation.14 This increase in ES is first detectable in circulation after day 45 in standard-sized horses, with levels greater than 6 ng/mL in pregnant mares. The circulating levels of ES continue to increase from this point on, due to production by the CL and also later during gestation by the fetoplacental unit. ES remains elevated throughout gestation, peaking at approximately days 150–180 and slowly declining as parturition approaches.14 Therefore, ES is a useful diagnostic tool for pregnancy from approximately day 45 until near term. If the timing of the diagnosis is not critical, testing a week or a few weeks after 45 days of gestation will certainly provide a definitive diagnosis. The only exception to this rule is miniature horses. Mins have a higher baseline level of ES and the peak seems to be later in gestation. Therefore, the recommended window for miniature horses is after 80 days of gestation and ES must be greater than 60 ng/mL to be consistent with pregnancy (http://www.vetmed.ucdavis.edu/phr/labs/endolab/index.cfm).

Finally, estrogens have also been used as a measure of fetal wellbeing and/or placental health. The rationale for this use comes from the fact that during mid and late gestation estrogen precursors are synthesized by the fetal gonads and the aromatization to estrogens occurs in the fetoplacental unit. Therefore, a healthy fetus and placenta are necessary for adequate estrogen production. In addition to this hypothesis, estrogens decrease rapidly after induction of abortion with prostaglandins16 and field studies also suggest that circulating concentration of estrogens are reduced in mares affected by placentitis.15 However, more research is necessary in this field using LC-MS technology to elucidate the changing patterns of steroids during late gestation in the mare, as previous research is based in immunoassays that evaluate total estrogens instead of specific estrogens. Recent data using LC-MS found an association between experimentally induced placentitis and a decrease in circulating 17β-estradiol sulfate.17

In summary, current testing for estrogens is useful to diagnose pregnancy after 45 days of gestation (ES > 6 ng/mL) in standard size horses and after 80 days of gestation (ES > 60 ng/mL) in miniature ponies.

4. Anti-Müllerian Hormone

Anti-Müllerian hormone (AMH) is probably the most recent endocrine marker developed into a diagnostic tool for equine reproduction. In the last decade, several scientific studies have established several diagnostic uses of AMH in both males18 and females.19 For males, AMH has advantages over testosterone and ES in the diagnosis of cryptorchidism.20 For mares, AMH has been proposed as an endocrine test with a number of useful diagnostic capabilities. It was first proposed as a replacement or a complement to the granulosa cell tumor (GCT)21–23 panel that included inhibin, testosterone, and P4. In GCTs there is a hormonal component that leads to an increase in inhibin (> 0.7 ng/mL) and T (> 45 pg/mL) and a decrease of P4 (< 0.5 ng/mL). However, as with most diagnostic tools there is rarely complete agreement among all parameters; levels are marginally outside the normal ranges and/or they can be confounded by other conditions. According to the literature, the sensitivity of these endocrine markers is as follows: inhibin is elevated in approximately 80–87% of tumors, and testosterone in approximately 48–54% of tumors.22 In addition to the sensitivity of these tests, they are also confounded by the fact that both hormones have been reported to be elevated during pregnancy in the mare. AMH offers greater sensitivity, with elevated AMH levels (> 4.0 ng/mL) in 98% of confirmed GCT tumors, and is not confounded by pregnancy as AMH remains relatively stable in circulation re-
gardless of circadian rhythms, seasonal changes, and pregnancy status.23

In addition to the diagnostic use of AMH in GCTs, there is a new and unique diagnostic use of AMH for the mare. As in other species, AMH proves to be a diagnostic marker to predict ovarian follicular reserves. AMH in the mare is expressed in pre-antral and antral follicles in the ovary, with the exception of primordial follicles and antral follicles greater than 30 mm in diameter.24 AMH plays an important role by inhibiting the recruitment of primordial follicles into follicular waves. As a result, AMH is strongly correlated with the number of antral follicles.23 In addition, both AMH and antral follicle counts are a reflection of the number of primordial follicles and therefore of the follicular reserve.24 Furthermore, in human medicine AMH has also been shown to have some predictive ability for the fertility of older women.25-27 This has not yet been shown in the horse, but is another potential use of AMH for the mare, given that the importance of follicular reserves might play an important role as a predictor of fertility especially in older mares.

5. Equine Metabolic Syndrome and Pituitary Pars Intermedia Dysfunction

Equine metabolic syndrome (EMS) and pituitary pars intermedia dysfunction (PPID) are two endocrine dysfunctions that affect reproduction. There is a relatively small amount of scientific literature regarding the effects of EMS or PPID on reproduction, yet both seem to negatively affect the reproductive health of the mare. EMS mares exhibit altered reproductive cyclicity, with loss of the seasonal anovulatory period28 and prolongation of the inter-ovulatory periods and luteal phases.29 Mares with PPID often suffer from persistent uterine infections, cycle irregularities, and difficulties carrying healthy foals to term.30 From an endocrine perspective these conditions tend to overlap.31 Horses with EMS have insulin resistance (IR) characterized by hyperinsulinemia and anecdotally develop PPID. PPID horses can also be affected by insulin resistance but are characterized by increased adrenocorticotropic hormone (ACTH).

In addition to clinical signs such as general or regional adiposity and a history of or predisposition to laminitis, horses with EMS can be diagnosed endocrinologically based on elevated insulin concentrations after an overnight fasting period. Thresholds delineating hyperinsulinemia are reached when insulin concentrations are greater than 20 μIU/mL.31 In addition, dynamic testing for evaluation of insulin sensitivity can be performed with an oral sugar test by collecting a basal blood sample, followed by oral corn syrup, followed by a second blood sample 60 minutes after the syrup administration (post sample insulin > 60 μIU/mL in horses with EMS). For horses with PPID, determination of circulating ACTH alone can be diagnostic (ACTH > 35 pg/mL; there are seasonal variations and seasonally adjusted ranges); however, a thyrotropin-releasing hormone (TRH) stimulation test seems to be more sensitive for the horses with an early onset of the disease. In case of a TRH stimulation test, a basal blood sample is followed by TRH (IV injection of TRH, 1 mg/mL) and a second blood sample is collected 10 minutes after the TRH administration (post-TRH ACTH level > 110 pg/mL in horses with PPID). Because increased regional adiposity and/or predisposition for laminitis are clinical signs sometimes present in both endocrine disorders, it is recommended to test for both endocrine disorders when trying to accurately diagnose EMS and/or PPID.

6. Conclusion

Endocrine markers are useful diagnostic tools when evaluating the reproductive status of the mare. There are well established uses for P4, ES, and AMH for the mare. Reproductive endocrinology is still an active field of research as new technology becomes available. Current research is focused on developing new diagnostic markers for fertility and for early markers of disease, especially during late pregnancy in the mare given that placentitis is still a devastating loss to the industry. Currently different steroids and miRNAs are being evaluated as diagnostic tools and have promising utility as new technology is available for researchers (LC-MS for steroids and RNA sequencing for miRNAs). It is very important, however, to understand the current limitations and adequate uses of the diagnostic markers. The inherent variations that endocrine markers are subject to among individual horses and the different assays used by different laboratories are particularly significant. It is always recommended to refer to the preferred clinical laboratory for advice regarding the adequate test, timing for each test, proper sample to obtain, and the best way to handle it to prepare for shipping, as they will be the ones interpreting the results within their reference ranges and with knowledge of each test’s limitations.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

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How to Use Assisted Reproductive Techniques for Managing the Sub-Fertile Mare

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1. Introduction

The main methods for assisted reproduction applicable to management of the sub-fertile mare currently are intracytoplasmic sperm injection (ICSI), oocyte transfer (OT), and cloning. ICSI and OT require oocytes to be collected from the donor mare. For ICSI, practitioners typically harvest oocytes from donor mares at their practice and then ship the oocytes to a laboratory equipped to perform the oocyte maturation, sperm injection, and embryo culture procedures. The resulting embryos may be shipped back to the practitioner for transfer or may be transferred at the ICSI facility. Oocyte transfer—the surgical transfer of a mature oocyte to the oviduct of an inseminated recipient mare—is a procedure that the practitioner may perform entirely within their practice. This technique offers a method for production of foals from sub-fertile mares via assisted reproduction if there are no ICSI facilities available. Cloning is applicable if the sub-fertile mare does not produce viable oocytes due to age or ovarian disease; the cloned filly resulting from the procedure can then be bred to yield foals.

2. Materials and Methods

Detailed methods for the procedures used for the assisted reproduction techniques given above have been presented at AAEP previously. These include methods for:

- Recovery of in-vivo matured oocytes from the dominant stimulated follicle via aspiration through the flank
- Handling of in vivo-matured oocytes for shipment to the laboratory
- Recovery of oocytes via transvaginal ultrasound-guided follicle aspiration (TVA)
- Handling of immature oocytes for shipment to the laboratory
- Oocyte transfer
- Tissue collection for nuclear transfer (cloning)

This how-to paper will go over some of the factors to be weighed when thinking of managing a sub-fertile mare using assisted reproduction. Basic parameters of ICSI, OT, and cloning to keep in mind when making clinical decisions to use these techniques are as follows:

ICSI

The ICSI Laboratory

Effective equine ICSI laboratories are only available in some countries; thus, ICSI may not be a possibil-
ity for some practices. It is a huge undertaking to attempt to set up an equine ICSI laboratory, and even when set up, new laboratories are often not successful. If an effective laboratory is available, my strong suggestion is to ship oocytes to that laboratory; if no ICSI laboratory is available, consider shipping oocytes internationally, performing OT, or recommending cloning.

International shipment of immature oocytes is a relatively simple procedure. Oocytes are placed in a suitable passive insulated device, set up at room temperature, and shipped via a standard overnight delivery service. Typically, international shipment by a delivery service will take 2 days. At Texas A&M, we have had good blastocyst rates with research oocytes shipped from France, with a shipment time of approximately 50 hours. However, if resulting embryos are to be transferred for pregnancy, the health regulations can be complex. International oocyte shipment requires meeting the same regulations set up for import of semen and embryos into the country in which the laboratory is established, and thus often quarantine and testing of the donor mare is necessary for each oocyte harvest. For the United States, a new import permit is needed for each shipment.

When choosing an ICSI laboratory to which to send oocytes, the practitioner should ask what the laboratory’s success rate is in terms of percentage of blastocysts achieved per injected oocyte and the ongoing pregnancy rate (with heartbeat) after transfer. It would also be good to know the numbers of ICSI cases performed (one case referring to all the oocytes collected from one mare in one session). Currently, there are only a few laboratories in the world that have published effective equine ICSI results (i.e., >25% blastocysts per injected oocyte when using research mares and stallions); others report good rates anecdotally. The efficiency decreases when clinical work is performed, due to mare age, cause of subfertility, and variation in sperm quality—the rate of blastocyst development per injected oocyte can be much lower depending on type of clinical caseload, and still be clinically useful.

Now that ICSI is becoming more accepted as a technique for equine clinical reproduction, many larger equine reproduction centers are attempting to establish this technique. Remember that anyone with the capability of injecting a sperm into an egg with a micromanipulator can say that they are doing ICSI, but the important thing is whether a viable embryo results from the procedure. For some reason, production of embryos for equine ICSI seems to be more difficult, or at least technically different, than that for other species. Technicians experienced in human ICSI may produce no blastocysts when performing equine ICSI.

Oocyte Recovery and Shipment for ICSI

ICSI is more efficient when immature oocytes are recovered from all immature follicles present on the mares’ ovaries, followed by in vitro maturation of the recovered oocytes. The practitioner should strive to attain a 50% or greater oocyte recovery rate on transvaginal aspiration of immature follicles, aspirating all follicles greater than 5 mm in diameter. This typically results (in Quarter-type mares) in aspiration of approximately 12 follicles and recovery of approximately six oocytes per aspiration session, of which four oocytes undergo successful maturation in vitro with subsequent ICSI. If only the dominant stimulated preovulatory follicle is aspirated, recovery rates are approximately 80%, with only one mature oocyte to undergo ICSI. Some practitioners do both: follow the preovulatory follicle and stimulate it, then during the TVA session recover oocytes from both the preovulatory follicle and the subordinate follicles present on the ovary. Interestingly, there seems to be no effect of this timing, either positive or negative, on the developmental competence of immature oocytes from subordinate follicles when compared with aspirating immature follicles during diestrus.

Although the above “combined” approach yields both quantity (the immature oocytes) and quality (the preovulatory oocyte), the two kinds of oocytes are ready for fertilization at different times. This requires ICSI to be performed at two separate times, and thus the expense to the client is increased and the return from ICSI of the one preovulatory oocyte is low. In clinical mares at Texas A&M, our blastocyst rate for in vivo–matured oocytes from the dominant stimulated follicle is only slightly higher than that for in vitro–matured oocytes (38 vs 23%, respectively per injected oocyte), thus in our hands, the increase in viability of the preovulatory oocyte does not make up for the fact that only one oocyte is available.

Immature oocytes can be shipped at room temperature by overnight courier, as noted above. In contrast, the maturing oocyte from the stimulated preovulatory follicle must be shipped in culture medium in a portable incubator; we try to keep the temperature between 37 and 38.2°C. Some airlines do not want to accept active devices and so such incubators may have to be transported by car.

Recovery of oocytes from immature follicles can be performed on a set schedule (i.e., once every 14 d), without checking the mare in between. At Texas A&M, because each recovered oocyte involves 12 days of monitoring and handling as it progresses through maturation, ICSI, and embryo development, we perform TVA on Mondays, Tuesdays, and Wednesdays so that ICSI is performed on Wednesdays, Thursdays and Fridays. The weekends involve embryo evaluation, handling, and shipment only. In contrast, recovery of the maturing oocyte from the dominant stimulated follicle requires examining mares repeatedly to monitor follicle activity and evaluate the size and appearance of the preovulatory follicle, timing gonadotropin stimulation of the dominant follicle, and aspirating the follicle at a
set time after gonadotropin administration. Typically, the gonadotropin stimulation is given on the day that the dominant follicle reaches receptive diameter (based on mare history or typical receptive size for breed) or appearance on ultrasonography. A workable schedule is to give the gonadotropin stimulus in the afternoon of Day 1, aspirate the follicle 24–28 hours later on the afternoon of Day 2, and immediately ship the oocyte by courier to the laboratory where it is subjected to ICSI the morning of Day 3. These steps are difficult to organize to a set schedule and so may result in oocytes being recovered when a laboratory will not receive them or when they may result in significant after-hours charges for handling and micromanipulation.

Although the above drawbacks exist for utilization of the dominant stimulated follicle, oocyte recovery from this follicle is much easier and initially more rewarding than aspiration of immature follicles, so practices just starting oocyte recovery may want to start by performing preovulatory follicular aspiration.

Oocyte Transfer
Because OT involves standing flank laparotomy on a recipient mare, it is best conducted when a single oocyte of high viability is available. Thus, OT is most suitable for use with the in vivo-matured oocyte recovered from the dominant stimulated follicle.

It is possible to use OT with multiple in vitro-matured oocytes (such as after collection of immature oocytes from TVA of all immature follicles, or recovery post-mortem); however, the pregnancy rate per oocyte transferred is very low because: 1) the maturation status of the oocytes is unknown at the time of transfer (the cumulus is left on so that the oocytes will “stick” in the oviduct, thus staging the meiotic status by viewing the polar body is not possible), and 2) the developmental competence of in vitro-matured oocytes is lower than that for in vivo-matured oocytes recovered from the stimulated preovulatory follicle. In my opinion in the case of multiple oocytes, it is best to transfer all oocytes (maximum, 12 per oviduct) to one or two recipient mare(s), then to flush the uterus for embryo recovery—this has been performed successfully 9–10 days after OT in a commercial program—and perform standard embryo transfer (ET) to secondary recipients with any recovered blastocysts. This has the drawback of potential inefficiencies at uterine flush and at ET, but is preferable to trying to perform a surgery for each of multiple oocytes, with a low chance of pregnancy per surgery. All procedures for OT are workable within a well-equipped practice. Oocytes may be recovered from the stimulated preovulatory follicle with a needle placed through the flank, eliminating the need to purchase and learn to use a TVA system. Recovery rates with this system are similar to those with transvaginal aspiration. If the oocyte is harvested close to the time of ovulation, it can be held for a few hours without a CO2 incubator or need for gassing, if medium with a nonbicarbonate buffer system such as in M199 with Hanks’ salts with 10% fetal bovine serum (FBS), is used. The oocyte may be placed in this medium in a capped tube in a water bath. The transfer procedure is straightforward and is performed via standing flank laparotomy.

The OT process is robust; within broad limits there is little effect of variation in factors such as time from donor gonadotropin administration to follicle aspiration, time from oocyte recovery to transfer, or time of recipient follicle aspiration in relation to insemination or transfer.

The main drawback to OT is the labor entailed. Recipients must be exactly synchronized and must have their preovulatory follicle successfully aspirated (or be in anestrus or early estrus and be hormonally treated); the donor mare must be monitored for follicle activity and have her follicle successfully aspirated, the recipient must be inseminated (thus good-quality semen is required), and then the surgery must be performed and the recipient cared for afterward. When OT is used clinically with old, sub-fertile donor mares, the foaling rate is only approximately 25% per oocyte transferred therefore 75% of the time this labor will not result in a foal. However, it is a viable method for producing foals from mares that cannot produce foals via natural conception or ET.

Somatic Cell Nuclear Transfer (Cloning)
Cloning is an effective method to produce a young, fertile filly with the genetics of the original donor. This filly can then be bred throughout its life—including via assisted reproductive technologies—to produce foals carrying the original donor mare’s genetics.

Cloning typically involves transfer of the donor mares’ genome (via the nucleus of one of her somatic cells) into a host oocyte obtained from another mare. Host oocytes are typically obtained from ovaries recovered from an abattoir. The mitochondria of the resulting foal will be that of the host oocyte, not of the original donor mare. It is unknown whether this has any effect on the cloned offspring but the client must be informed of this, and educated to understand what it means. If this is important to your client, this can be avoided by performing nuclear transfer on oocytes recovered from mares that are maternally related to the donor.

Cloned foals and their progeny are not able to be registered with many breed registries. If registration is important to your client, then they should check with their breed registry to determine the regulations regarding clones.

Cloning is many times more expensive than is one cycle of ICSI or OT; however, once the cloned filly is produced, the expense of achieving foals from her is that of standard reproductive procedures. Thus, over the cloned filly’s life span, her ability to produce
numerous foals, especially using techniques such as ET, will lead to a cost per foal that is much less than if multiple ICSI or OT cycles are performed on the original sub-fertile donor mare.

There is only one commercial company in the United States that clones horses. There are two commercial companies in Argentina that clone horses. Thus, for practitioners with patients in other countries, it is necessary to send cells internationally to produce a cloned foal. This will require testing and quarantine of the donor animal before the tissue sample is obtained, but such testing is necessary only once for obtaining the tissue sample. It is advisable to plan the cell preservation in advance, arranging all import requirements and paperwork before the tissue is obtained. Although tissue culture may be conducted locally and the frozen cultured cells shipped to the cloning laboratory, some laboratories have found variable results with these cells and prefer to have the tissue sample shipped directly.

Factors Regarding the Choice of Assisted Reproductive Technologies for a Given Sub-Fertile Mare

Oocytes

If the mare’s subfertility is oocyte related, i.e., she produces no oocytes or produces only nonviable oocytes (e.g., due to extreme age, exposure to toxins, disease, or removal of the ovaries), neither ICSI nor OT will be useful, and cloning should be considered.

Genetics

If the mare’s oocyte-related subfertility is genetic, such as a mutation or a chromosomal abnormality, cloning is possible but the chromosomal abnormality will also be present in the cloned filly, thus obtaining offspring from this genetic line through the cloned filly will still not be possible. Technical procedures for correcting mutations in a specific cell line by gene “editing” are currently under development and are promising, but are not yet ready for clinical use. Once this becomes feasible, in theory the mutation could be corrected in cells in culture, and those cells used for cloning, producing a cloned filly with the genetics of the donor mare but without the mutation.

Age

Interestingly, mare age itself does not seem to be a major factor in the success of ICSI or OT. This is notable in light of the pioneering paper in OT, in which oocytes from old mares (> 20 y) had a significantly lower pregnancy rate after OT than did oocytes from young mares. However, that study was performed with research animals and the young mares were 6–10 years of age. In clinical practice, in which essentially all mares entering the OT program are greater than 17 years of age, no significant effect of donor age has been found in OT. Our data with ICSI also suggests no significant effect of donor age on the oocyte recovery rate, maturation rate, or rate of blastocyst development after ICSI until mares are at least 24 years old; however, the number of follicles declines significantly with age, thus fewer oocytes are recovered, reducing the efficiency per aspiration performed.

If mares are so old that they bring up only one or two follicles per cycle, and/or only cycle a few times per year, assigning the mare to recovery of the oocyte from the dominant stimulated follicle should be considered for two reasons: 1) the recovery rate is higher, and 2) the quality of the oocyte should be higher. However, it is possible that aged mares do not have the appropriate hormonal environment to raise preovulatory follicles up with maximal oocyte viability, and thus that recovering immature oocytes, even if only one or two per cycle, might provide better-quality oocytes. The solution here remains to be determined.

Idiopathic Infertility

In some mares, idiopathic infertility seems to be oocyte-related, as numerous attempts to produce foals from these mares’ normal-appearing oocytes via ICSI or OT are unsuccessful.

Hemorrhagic Anovulatory Follicles

Mares with recurring hemorrhagic anovulatory follicles are good candidates for TVA of immature follicles, as recovering immature oocytes and maturing them in vitro avoids the problems associated with preovulatory follicle development in these mares. Recovery of multiple immature oocytes from these mares leads to selection of ICSI as the method of choice for their fertilization.

Chronic Uterine Infection

If the mare has a chronic uterine infection, she is a poor candidate for TVA. This is because the vagina will be contaminated with the causal organism, and during TVA a needle is passed through the vaginal wall into the peritoneum and ovary, thus risking induction of peritonitis or ovarian infection from microorganisms carried in with the needle. In such mares, we recommend trying to clear the infection before TVA is performed. Given that the mare will not be inseminated again, this is sometimes possible; extreme methods such as cervical wedge resection or chemical curettage are applicable as the mare will not need to carry an embryo again. Clearing of the infection should be monitored by lack of fluid in the uterus on transrectal ultrasound examination and lack of a vulvar discharge, and immediately before performing the TVA, checking for lack of exudate in the vagina on speculum examination. Clearing of the infection should not be monitored by taking a uterine swab, as performing any transcervical manipulation, including the swab procedure, may reintroduce organisms into an extremely susceptible uterus and cause the infection to recur.
If the uterine infection cannot be cleared, it may be possible to perform TVA on the mare successfully if she is managed appropriately with systemic antibiotics, without increased incidence of negative adverse effects. Alternatively, TVA can be avoided and the mare assigned to aspiration of the dominant stimulated follicle via flank aspiration. Unfortunately, as noted above, aspiration of the dominant stimulated follicle greatly reduces the efficiency of ICSI per cycle, given that the oocyte is recovered only 80% of the time, and if recovery is successful, only one oocyte is available for ICSI.

3. Results

ICSI

If ICSI is conducted using TVA of all immature follicles and in vitro maturation of the recovered oocytes, reported blastocyst production is approximately 50–100% per aspiration. What we find in our program is that many mares yield no blastocysts after an aspiration, and others can yield several blastocysts. This may be related to individual differences in mare oocyte quality, or possibly to some effect (currently unstudied) of the stage of cycle on oocyte developmental competence.

The effect of the cause of subfertility on results after ICSI is unclear. Colleoni et al. found no difference in blastocyst development between eight mares presented for ICSI with reproductive disorders and 22 mares that were reproductively sound. We do not receive a reproductive history from many mares that present for TVA at Texas A&M, nor from the mares from which we receive shipped oocytes. If we separate the mares by the stallions used—whether the stallion is available for breeding only via ICSI, due to limited stores of frozen semen—we might suppose that the mares going to ICSI-only stallions would tend to be more reproductively normal than would mares having ICSI performed to a stallion available for standard breeding techniques. In our data, there is a slight difference in blastocyst rates per injected oocyte between these two stallion types (25 vs 21%, respectively, n = 574 and 399, respectively).

The pregnancy rate after transfer of ICSI blastocysts may be good (82% for fresh embryos, 69% for frozen embryos) but embryo loss can be high (e.g., 20–30% of established pregnancies). Foals produced from ICSI embryos seem to be completely normal, although to the best of our knowledge no systematic studies on this have been conducted.

Oocyte Transfer

Reports on clinical use of OT for management of sub-fertile mares have found a 19–29% ongoing pregnancy or foaling per (in vivo-matured) oocyte transferred. Again, initial pregnancy rate may be higher, but 21–30% of the pregnancies are lost. Foals produced from OT seem to be normal.

Somatic Cell Nuclear Transfer (Cloning)

Commercial companies do not release their data; thus it is unclear what proportion of attempts at nuclear transfer at these facilities produce live foals. In our research program at Texas A&M, we have produced live foals from each of the nine horses we have attempted to clone; thus, it is possible for this to be an effective technique.

Foals produced by nuclear transfer can have health problems at birth. In a retrospective study of foals produced by nuclear transfer at Texas A&M, we found that 50% of cloned foals produced were completely normal, and 50% had some problem at birth, most commonly maladjustment, enlarged umbilicus, and contracture of the front limbs. Two of 14 foals died within 7 days of birth; in the remainder any problems present resolved with treatment.

Although to the best of my knowledge there are no reports on fertility of cloned horses, the cloned fillies produced in our laboratory have had normal fertility, with owners reporting numerous foals produced from each by ET.

4. Discussion

Equine practitioners who were in practice before these assisted reproductive procedures were available understand the amazing relief of being able to offer clients methods to obtain foals from valuable mares whose uterus, oviducts, or even ovaries are nonfunctional. More extensive availability of ICSI will allow practitioners across the globe access to this effective technique. I remain surprised at how few practitioners have used OT, an effective method that can be conducted in-house in a practice with a standing surgery facility, with minimal additional equipment required. Having worked with ET, OT, ICSI, and cloning, when registration is not an issue I believe that cloning should be considered by more clients. Once the cloned filly is produced, the headache and expense of conducting repeated assisted reproductive techniques—often with negative and frustrating results—is over.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author oversees a commercial equine intracytoplasmic sperm injection (ICSI) program that could benefit financially from performing ICSI on oocytes shipped to the laboratory by referring veterinarians.

References and Footnotes


*aEquitainer, Hamilton Research, Inc., Ipswich, MA 01938.*

*bViaGen, Cedar Park, TX 78613.*
How to Use Endocrine Therapy to Manage the Sub-Fertile Mare

Kristina Lu, VMD, DACT

1. Introduction
Sub-fertile mares present endocrinological challenges both in their potential pathology and variable responses to endocrine therapy. Despite this, achieving a live foal from a sub-fertile mare frequently depends on the veterinarian’s application of appropriate endocrine therapy.

2. Follicular Growth Stimulation
Hormonal stimulation to manage the transition period in normal mares is well reviewed and includes the use of gonadotropin-releasing hormone, gonadotropins, ovulation-induction agents, progestogens, and dopamine antagonists (Table 1). Sub-fertile mares can include mares that seem to persist in anestrus or transition well beyond other mares in the same environment. The reasons for this are poorly understood and likely due to multiple causes. Many of the same treatments used for expediting the transitional period are used in mares with follicular activity during the breeding season to schedule or induce ovulation.

There is intriguing potential in the use of recombinant equine gonadotropins. Recombinant gonadotropins do not require obtaining equine pituitaries and avoid the concern about contamination with other hormones or infectious agents. Potential applications for sub-fertile mares include superovulation to increase the number of oocytes or embryos for assisted reproductive techniques, superovulation to increase the number of “targets” for sub-fertile stallions, and stimulation of follicular activity in the deeply anestrus mare.

3. Ovulation Induction
Reliable induction of ovulation is a valuable tool to aid in optimizing the breeding of sub-fertile mares.

Two more commonly used products are human chorionic gonadotropin (hCG) and deslorelin acetate (DA). The efficacy of DA (1.8 mg, IM) was compared with hCG (2500 IU, IV). There was no difference in the percentage of mares that ovulated within 48 hours after DA compared with hCG. There was a significant increase in the percentage of mares that ovulated within 24 hours after administration of hCG compared with DA, although it was considered the dominant follicle in both groups may have been influenced by endogenous luteinizing hormone promoting early ovulation. A significant difference in follicle size was noted between groups, with the DA group having a follicle size of 39.9 ± 4.5 mm, and the hCG group having a follicle size of 41.3 ± 4.3 mm. However, the average intervals to ovulation were 41.4 ± 9.4 hours for DA and
44.4 ± 16.5 hours for hCG, due to a number of mares in both groups having prolonged intervals to ovulation and nonovulation in the hCG group.⁵ The variation in response to hCG administration over time to individual mares has been theorized to be the result of anti-hCG antibody induction; however, one study determined that there was no correlation between either the hCG-invoked immune response, or the ovulation time and pregnancy rate.⁴ Furthermore, cross-reactivity studies showed no significant binding between plasma anti-hCG antibodies and either equine-luteinizing hormone (eLH) or equine chorionic gonadotropin (eCG).⁴

Ovolatory agents may improve reproductive efficiency beyond ovulation timing. Köhne et al⁴ reported that progesterone concentrations 5–15 days after ovulation were higher in mares whose ovulations were induced with hCG (n = 14) compared with mares whose ovulations were not induced (n = 28).⁵ Nagao et al⁵ evaluated the use of deslorelin to reliably induce double ovulation to optimize embryo production.⁶ After luteolysis 8 days post ovulation, mares were monitored until two follicles (20–25 mm in diameter) were detected. At this time, 100 μg DA was administered every 12 hours. Ovulation was induced with 2500 IU hCG. The number of days until ovulation was 3.5 days in the deslorelin-treated group and 6.7 days in the control (saline-treated) group. The interval to ovulation was shorter in DA-treated hCG-induced mares (35 ± 6.1 h) compared with saline-treated mares (42 ± 5.1 h). The average number of ovolutions per estrous cycle and the number of recovered embryos per estrous cycle was greater in the deslorelin-treated group. There was no difference in the number of embryos recovered per ovulation.⁶

### 4. Mating-Induced Endometritis

Sub-fertile mares frequently suffer from delayed uterine clearance after breeding. Oxytocin is one of the most commonly used ecbolics to aid in post-breeding uterine clearance. Administration of 10 IU oxytocin IV induced a similar number of uterine contractions in normal mares compared with mares with delayed uterine clearance. The duration of uterine contractions was approximately 24 minutes.⁷ Dose of oxytocin has an effect on contractility, whereby higher doses lead to segmental contractility that may impede peristaltic clearance, whereas lower doses promote evacuation by coordinated peristalsis.⁸⁹ Carbetocin is a long-acting oxytocin analog not available in the United States. Its efficacy has been studied in an ex vivo myometrial tissue model, revealing a half-life of 17 minutes compared with the oxytocin half-life of 6.8 minutes.¹⁰ Ecbolic effects can also be achieved by the use of cloprostenol; however, this has been shown to deleteriously affect progesterone production from the developing corpus luteum.¹¹¹² Glucocorticoids have been used to control post-breeding endometritis. Compounds investigated include prednisolone acetate and dexamethasone.¹³¹⁴ In a fertility trial evaluating the use of 0.1 mg/kg prednisolone acetate, none of fifteen mares achieved pregnancy without prednisolone treatment whereas 64.5% achieved pregnancy with prednisolone treatment.¹³ Dexamethasone (0.1 mg/kg IV) administered once at the time of breeding was evaluated for efficacy in reducing breeding induced inflammation and increasing pregnancy rates in susceptible mares. Pregnancy rates were significantly improved in mares with at least three risk factors (abnormal reproductive history, positive endometrial culture, at least 2 cm endometrial fluid prior to breeding, abnormal perineal conformation or unrepaired Caslicks after foaling, abnormal cervix, greater than 1.5 cm post-breeding fluid, post-breeding fluid persisting beyond 36 h, and abnormalities of the reproductive tract).¹⁴ A dose of 0.1 mg/kg IV dexamethasone with intrauterine infusion of 10⁵ colony forming units (CFU) of E. coli was used to assess changes in pro- and anti-inflammatory cytokine expression. Treatment with dexamethasone at the time of breeding caused a significant effect on endometrial expression of cytokines and serum amyloid A (SAA) in susceptible

### Table 1. Drug Doses From Literature Sources Described in the Text

<table>
<thead>
<tr>
<th>Drug</th>
<th>Indication</th>
<th>Dose</th>
<th>How to Treat the Sub-Fertile Mare</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deslorelin acetate</td>
<td>Ovulation induction</td>
<td>1.8 mg</td>
<td>30–40 mm follicle during estrus</td>
</tr>
<tr>
<td></td>
<td>Inducing double ovulation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Human chorionic gonadotrophin</td>
<td>Ovulation induction</td>
<td>2,500 IU</td>
<td>&gt;35 mm follicle during estrus</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>Uterine contractility</td>
<td>10–20 IU</td>
<td>Every 6 hours beginning 4 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>after breeding (Nie 2003)</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>Anti-inflammatory</td>
<td>0.1 mg/kg</td>
<td>At time of breeding</td>
</tr>
<tr>
<td>Prednisolone acetate</td>
<td>Anti-inflammatory</td>
<td>0.1 mg/kg</td>
<td>From ovulation induction to ovulation</td>
</tr>
<tr>
<td>Pergolide</td>
<td>PPID</td>
<td>0.002 mg/kg</td>
<td>Once daily</td>
</tr>
<tr>
<td>Cyproheptadine</td>
<td>PPID</td>
<td>0.25 mg/kg</td>
<td>Twice daily</td>
</tr>
<tr>
<td>Levothyroxine sodium</td>
<td>Insulin insensitivity</td>
<td>0.1–0.15 mg/kg</td>
<td>One daily</td>
</tr>
<tr>
<td>Metformin hydrochloride</td>
<td>Insulin insensitivity</td>
<td>30 mg/kg</td>
<td>Two to three times daily</td>
</tr>
<tr>
<td>Progesterone</td>
<td>Pregnancy maintenance</td>
<td>300 mg</td>
<td>Daily</td>
</tr>
<tr>
<td>Altrenogest</td>
<td>Pregnancy maintenance</td>
<td>0.044 mg/kg</td>
<td>Daily</td>
</tr>
</tbody>
</table>

**How to Treat the Sub-Fertile Mare**

- **Glucocorticoids**: Prednisolone acetate and dexamethasone are commonly used to control post-breeding endometritis.
- **Antibiotics**: E. coli is a common cause of post-breeding endometritis. In a fertility trial, a dose of 0.1 mg/kg IV dexamethasone with intrauterine infusion of 10⁵ CFU of E. coli was used to assess changes in pro- and anti-inflammatory cytokine expression.
- **Cytokine expression**: Treatment with dexamethasone at the time of breeding caused a significant effect on endometrial expression of cytokines and serum amyloid A (SAA) in susceptible mares.
mares. Of the pro-inflammatory cytokines, expression of IL-1 was decreased, expression of IL-6 was increased immediately after dexamethasone administration, and IL-8 (a potent chemoattractant for trans-epithelial migration of polymorphonuclear cells (PMN)s into tissue) expression was decreased. The anti-inflammatory cytokines IL-10 and IL-1ra had increased expression following dexamethasone administration.15

5. Metabolic Syndrome
Insulin resistance can be associated with equine metabolic syndrome and pituitary pars intermedia dysfunction (PPID). Metabolic syndrome in horses is additionally associated with regional adiposity and a pro-inflammatory state. In humans, insulin plays a major role in regulation of ovarian steroidogenesis, follicular development, and granulosa cell proliferation.16 Research in other species suggests that maternal insulin resistance contributes to oxidative stress and mitochondrial dysfunction in oocytes.17 The intrafollicular environment and oocyte quality are also altered in mares with metabolic syndrome.18,19 Pregnant mares in the final third of gestation demonstrated lower insulin sensitivity, lower basal glucose clearance rate, and a lower acute insulin response to glucose compared with nonpregnant mares. Pregnant mares consuming a high starch feed had greater glycemic and insulinemic responses to feed than nonpregnant mares or pregnant mares consuming a diet high in fat and fiber. Monitoring the dietary energy content of feed may be of increased importance in pregnant mares.20 Evidence in other species also suggests that maternal obesity increases the risk of obesity and insulin resistance in offspring.21

Endocrine therapy for management of endocrine disease is complicated by the challenges of accurate diagnosis. Although not directly endocrine therapy, dietary modification and exercise are integral components of management. Pergolide is recommended for treatment of PPID (0.002 mg/kg, every 24 h, by mouth). Cyproheptadine (0.25 mg/kg, every 12 h, by mouth) may also be used typically to augment pergolide in horses with more advanced PPID. As a prolactin antagonist, the use of pergolide during late gestation may affect initiation of lactation.

In addition to diet and weight management, levothyroxine sodium and metformin hydrochloride can be used to manage insulin dysregulation. Levothyroxine sodium (0.1–0.15 mg/kg, every 24 h, by mouth) lowers body weight and improves insulin sensitivity in horses. Metformin hydrochloride (30 mg/kg every 8–12 h, by mouth) 1 hour before feeding or turnout may improve resting insulin concentrations and insulin sensitivity, and decrease blood glucose and insulin concentrations after feeding.22,23

6. Pregnancy Maintenance
The chance of pregnancy loss is always of great concern in sub-fertile mares. Progesterone and/or progestogen supplementation is commonly implemented to “prevent” abortion or at least to be seen to be making every attempt to prevent abortion. In a demonstration of their efficacy, progesterone and/or altrenogest maintained early pregnancy in ovariec-tomized recipient mares when mares were administered 300 mg progesterone daily or 0.044 mg/kg altrenogest daily.24 A combination of estradiol benzoate and a long-acting progestogen preparation was able to maintain pregnancy in anovulatory, transitional recipient mares.25 Protocols differ from that used to manage cyclicity in the mare in the time leading up to breeding.

The widespread administration of altrenogest to prevent pregnancy failure is not evidence based; however, positive effects on live-foal rates are possibly indicated in selected conditions including aged mares, endotoxemia, iatrogenic luteolysis, embryo transfer, twin reduction, and placentitis.26 Plasma progestogens can be elevated in compromised pregnancies, and there is some uncertainty as to the value of exogenous progestogen administration if plasma progestogens are already elevated.27

Estrogen therapy for pregnancy maintenance is considered controversial and is not widely discussed in the literature. Estrogens decrease significantly in mares with experimentally induced ascending placentitis.28 One report describes a higher live-foal rate in mares assumed to be affected by placentitis supplemented with estrogens versus mares not supplemented with estrogens.29 However, in a study evaluating the last trimester of gestation with administration of letrozole, a potent aromatase inhibitor preventing the conversion of androgens to estrogens in the placenta, no changes were observed in the length of gestation, uterine artery hemodynamics, or neonatal viability. Foals from treated mares were significantly smaller than those of control mares at birth.30

Endocrine therapy is essential for managing sub-fertile mares. Appropriate therapy is guided by clinical observations; diagnostics, which are reviewed in another paper in this session; and response to treatment.

Acknowledgments
Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

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HOW TO TREAT THE SUB-FERTILE MARE


*Chorulon, Merck Animal Health, Summit, NJ 07940.  
SucroMate, Thorn Biosciences, Louisville, KY 40204.  
Prascend, Boehringer Ingelheim Vetmedica, St. Joseph, MO 64506.*
How to Utilize Endometrial Culture, Cytology, and Biopsy to Manage the Sub-Fertile Mare

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1. Introduction
An economically successful brood mare needs to produce a viable foal annually. For this to occur, she needs to be in good physical condition, have regular estrous cycles, mate, conceive, maintain pregnancy, give birth, and raise a foal. If there is a breakdown in any of these areas she will become considered a “problem” mare. Consideration of breeding practices and fertility of the stallion is important before all the blame of subfertility is placed on the mare. Therefore, to manage the mare appropriately a complete reproductive examination is imperative to identify the potential cause of the mare’s subfertility. A complete reproduction evaluation can include the following: a complete history of the mare’s past reproductive performance; general physical condition; and body score, perineal conformation, transrectal palpation and ultrasonography, examination of the cervix; as well as culture, cytology, and biopsy of the endometrium. Additional procedures that may be used to identify the cause of subfertility are hysteroscopic examination, endocrine assays, cytogenetic testing, and activation of dormant Strep. zooepidemicus. Once an etiology has been determined, treatment and management can be orchestrated.

This paper will focus on uterine culture and cytology as a useful tool in the diagnosis of endometrial inflammation and an indicator of bacterial endometritis.1–3 Endometrial cytology has been described and related to bacteriological findings by several authors.4–7 Different methods to identify inflammatory cells (presence, type, and number), mucus, and debris have been described in the literature to include guarded swabs, cytology brushes, low volume lavage, and endometrial biopsy.4,6,7 The low-volume lavage technique has been demonstrated to be twice as sensitive as endometrial swabbing and nearly as efficient (90%) as endometrial biopsy for the isolation of causative microorganisms in mares with infectious endometritis.7,8 Bacteriological and cytological results obtained by endometrial biopsy are the most sensitive indicators bearing positive predictive value compared with results obtained by endometrial swab.9 Thus, bacteriological and cytological results obtained by endometrial biopsy are considered the “gold standard” in the diagnosis of endometritis.2,4

Endometrial biopsies can be indicated in barren mares, repeat breeders, early embryonic death or abortion, pyometra and mucometra, genital surgery, and fertility evaluation.2,6 Not only are they useful for culture and cytology as previously mentioned,
but they provide an endometrial biopsy score, which is an accepted marker of uterine health and predicted fertility. More than one sample from different areas of the uterus can be obtained to verify the repeatability of degenerative changes. The endometrium is classified according to the presence of inflammation (type and severity), endometrial gland density, periglandular fibrosis and gland nesting, and cystic glandular distension. As the number and severity of pathologies increase so does the category classification, whereas the potential of carrying a foal to term decreases. Category I has little or no pathologic changes with an 80–90% foaling rate. Category IIA has either slight-to-moderate diffuse superficial inflammatory changes, infrequent fibrotic changes involving individual glands (less than three layers of fibrosis), mild fibrotic nesting, or lymphatic lacunae. Mares with a Category IIA endometrium would be expected to carry a foal to term 50–80% of the time. Category IIB is any mare barren for 2 years or more, or with widespread diffuse, moderately severe inflammation, or more extensive fibrotic changes of individual glands with increased gland nesting. These changes lead to a 10–50% expected term foaling rate. Category III has widespread, diffuse, severe inflammation with extensive fibrosis and nesting. Unfortunately, the Kenny-Doig classification system described above does not take into account the amount of edema, lymphatic stasis, mitotic figures within the endometrial glands, or endometrial angioapathies that may be present within the endometrium.

2. Materials and Methods

Most subfertile mares have a pendulous uterus that sits cranially and ventrally in the caudal abdomen due to stretching of the broad ligaments with increased age and parity, decreased uterine contractility, and poor perineal conformation. These factors, combined with gravity, cause intraluminal fluid, inflammatory cells, bacteria, mucus, and debris to reside in the most dependent part of the uterus, usually the base of the uterine horns. An endometrial sample obtained by a guarded swab or brush would only reach an area of the uterine body just cranial to the cervix due to the swab's length. Therefore, in the author’s opinion, to obtain a representative sample of the uterine environment in these problem mares, culture and cytology should be performed with a low-volume lavage or endometrial biopsy.

Low-volume lavage is usually performed during estrus as described by LeBlanc by infusing the uterus with 60–150 mL of sterile saline or lactated Ringer’s solution. The mare’s perineal region is cleansed, especially between the vulvar lips. A sterile sleeve. Commercially obtained uterine lavage tubes or medical grade silicone tubing can be used. Sterile saline is infused into the uterus by attaching either a 60-mL catheter-tip syringe containing 60 mL of saline or a 150-mL bag of sterile saline to the end of the catheter. The uterus is massaged by transrectal palpation to distribute the fluid throughout the lumen, and subsequently, the effluent is recovered back into the attached sterile bag. If the mare is in heat and the fluid is trapped in the edematous endometrial folds, the administration of 10 IU oxytocin IV to stimulate uterine drainage through myometrial contractions is recommended. However, when a small volume is placed into a pendulous large atonic uterus it can be very difficult to retrieve, especially if it has dissipated into the horns and extensive transrectal manipulation can lead to contamination and increased procedure duration, which, in a field situation may not be optimal. The author therefore performs a low volume lavage using 1 L of sterile saline or lactated Ringer’s solution. A sterile flush catheter such as bivona® with a Christmas tree, and an extension set is connected to a sterile liter bottle of fluids. The catheter system is primed with fluid and placed into the uterus shielding the tip of the flush catheter with a sterile gloved hand as it enters the vagina, cervix, and uterus. The bottle of warmed fluids is inverted upside down and gravity allows influx into the uterus. The fluid disperses throughout the uterus by gravity rapidly. Removal of the fluid occurs with lowering of the bottle toward the ground, thus minimizing contamination. The sterile top is replaced and sealed with tape for delivery to the laboratory. The recovered effluent is evaluated for cloudiness and the amount of mucus. When using the smaller volume (60–150 mL) to obtain the precipitate, the sample is allowed to settle for at least 30–60 minutes or centrifuged at 400 × g for 10 minutes and all but 5 mL of the supernatant is discarded. The pellet is then sampled with a sterile cotton swab for culture and another for cytology. When 1 L is used, the laboratory at Hagyard Equine Medical Institute allows the bottle to sit for 1 hour. After the lavage effluent has settled, a 10-mL pipet is inserted to the bottom of bottle slowly and 10 mL of the sediment is drawn up. Five mL lavage sediment is placed in two 12 × 75-mm test tubes. The tubes are centrifuged at 400 × g for 1 min. The supernatant is discarded, and the pellet is resuspended in the small amount of fluid remaining in the bottom of the tube. One sample is used for culture and the other for cytology. Two cytology samples are made by rolling the cells onto a glass microscope slide. One is then Wright stained and the other Gram stained. A swab of the cellular material from the other tube is streaked on blood and MacConkey agar and incubated for 48 hours. Samples must be processed for culture within 8 hours because saline does not preserve bacteria.
Endometrial biopsies can be performed when the mare is in estrus or diestrus. If the mare is in diestrus, the author prefers to perform the procedure 6 days post ovulation so that prostaglandin can be administered to bring the mare back into estrus and open the cervix allowing any hemorrhage or contamination that occurred during the process to be evacuated. For the biopsy, the rectum is evacuated and the perineal area cleaned. The biopsy instrument is hand guided through the vagina and cervix into the uterus. The instrument is then identified per rectum and advanced to allow sampling at the base of a horn. If pathology has been noted on ultrasound, sampling of that area or horn on the ventral aspect of the uterus may be more representative. The sample is then removed from the biopsy basket with a 25-gauge needle so as not to destroy the sample architecture, and the biopsy is placed in 10% formalin or Bouin’s solution for fixation. The sample is then sectioned for histopathological examination. If the biopsy is to be used for culture and cytology then placing a sterile speculum at the base of a horn. If pathology has been noted on ultrasound, sampling of that area or horn on the ventral aspect of the uterus may be more representative. The sample is then removed from the biopsy basket with a 25-gauge needle so as not to destroy the sample architecture, and the biopsy is placed in 10% formalin or Bouin’s solution for fixation. The sample is then sectioned for histopathological examination. If the biopsy is to be used for culture and cytology then placing a sterile speculum in the vagina through which to pass the biopsy instrument allows less contamination on insertion and removal. The author has also placed a sterile sleeve over the biopsy instrument for passage through the vagina and into the cervix, at which point the biopsy instrument is pushed through the finger of the sleeve and inserted into the uterus. There may be some contamination on removal of the biopsy instrument; however, this has been found to be minimal. The sample is then smeared on MacConkey and blood agar for bacteriology and a slide is prepared for cytology.

3. Results

Cytological evaluation of any uterine sample should not only include the presence, type, and quantity of inflammatory cells, but also identify endometrial cells, red blood cells, bacteria, amount of mucus, debris, fungal elements or yeast, and anything else that is seen that would provide pertinent information i.e., urine crystals, squamous epithelial cells, sperm, and powder crystals. The presence of endometrial cells suggests that the sample is representative of the uterine environment, whereas the presence of stratified squamous epithelial cells suggests vaginal contamination or possible pneumomtra. Identification of the other parameters allows the clinician to devise an appropriate treatment plan. Slides should be reviewed first on 10× to scan for cellular material, then at 40× to quantitate cells, and oil immersion (100×) to quantify and identify bacteria. Ten fields should be examined and the average of the ten fields used to determine quantity. At Hagyard Laboratory, the inflammatory cells and bacteria are quantitated as follows:

- Rare: 0–1 per 5 fields
- 1+, Occasional, scant: 1–3 per field
- 2+, Moderate: 6–10 per field
- 3+, Heavy: 10–15 per field
- 4+, Gross: too numerous to count

Culture results should contain the name of the organism, the growth quantity, and an antibiotic susceptibility report. It should also be noted on the report if normal skin flora was present. At Hagyard Laboratory the growth is quantitated as follows:

- Scant: 10 colonies or less
- Light: growth on primary streak only
- Moderate: growth on secondary streak
- Heavy: growth on last streak

Endometrial biopsy provides histological identification of what type of inflammatory cells are present (i.e., neutrophils, lymphocytes, eosinophils), the severity, distribution (focal, diffuse) and the area within the endometrium in which they reside (i.e., luminal epithelium, interstitium, perivascular, periglandular). There is a seasonal and a hormonal influence on the endometrium with obvious differences between anestrus, estrus, and diestrus. Glandular density, epithelial height, and mitotic activity should be recognized along with glandular distension and nesting. The severity of fibrosis around individual glands and around nesting should be quantified. The quantity of blood vessels, and more importantly, the amount of elastosis or degenerative changes should be noted. To do this, a large and deep enough piece of endometrium is necessary to include the deeper vascular structures. Finally, the extent of lymphatic dilation or lacunae should be identified and reported. A biopsy report from a pathologist will take into account the presence and severity of the first three factors identified above to provide the Kenny-Doig grade, giving a predictive value or percentage for that mare to carry a foal to term. In addition, a histopathological description of other changes within the endometrium will be provided, commenting on all the anatomy described above. Further examination of the biopsy slide by a theriogenologist can provide a clinical interpretation of the changes and conditions present, with subsequent potential therapeutic recommendations.

4. Discussion

By identifying the underlying pathologies within the uterus, specific management and treatment of the individual sub-fertile mare is possible. On cytological examination, the inflammatory components most commonly identified are white blood cells (neutrophils). The presence of more than two white blood cells per high powered field (HPF) suggests that there is an inflammatory response. Degenerative versus nondegenerative neutrophils suggest chronic versus acute inflammation. Care must be taken in differentiating the dark staining nucleus nuclei of degenerative cells from yeast. Identification of eosinophils is suggestive of pneumovagina/
uteros and chronic inflammation or can be suggestive of fungal or yeast infection. The presence of red blood cells can suggest hemorrhage or trauma during sample collection. Red blood cells will be accompanied by the occasional white blood cell, without true inflammation being present. Identifying and quantifying the amount of mucus present is important given that mucus secretion increases during experimental uterine inflammation and in mares with delayed uterine clearance. Uterine debris can suggest chronic inflammation with increased cellular breakdown, delayed uterine clearance in older mares, or poor cervical relaxation in young mares. If the uterus does not contract effectively or there is poor lymphatic drainage, fluid and cellular debris (sloughed epithelial cells) are not extruded from the uterus and increased quantities are identified on cytology. The same occurs with the mare whose cervix does not relax, trapping fluid and cellular debris within the lumen. The presence of bacteria, specifically intracellular bacteria, is highly suggestive of infection, as is the presence of fungal elements or yeast. Identification of urine crystals (calcium carbonate or calcium oxalate) suggests that the mare has vesicovaginal reflux (pooling urine) in her uterus. The most common pathogen isolated in these situations is *Enterococcus faecalis*. Therefore, even if there is no observation of urine or urine crystals in the presence of *Enterococcus faecalis*, additional investigation is necessary. The presence of squamous epithelial cells is not common; however, it can signify that collection of the sample may have been difficult and that growth of normal skin flora may follow.

Culture of the low volume lavage more readily identifies the presence of Gram-negative bacteria (*E. coli* or *Klebsiella pneumoniae*), an advantage over other techniques, therefore identifying mares that may not have cultured positive previously. Antibiotic-sensitivity patterns further allow the appropriate antibiotic to be used in the treatment protocol.

On receiving a biopsy report from a pathologist, a practitioner is quick to identify the Kenney-Doig classification number assigned to the mare. Although this provides the client with a prognosis for their mare to carry to term, the veterinarian should identify the pathological changes described in the evaluation. By understanding the ramifications of these changes, therapeutic goals can be implemented. For example, the presence of acute or chronic inflammation necessitates further investigation to identify the cause of the endometritis. This may require correction of perineal conformation or cervical defects or the identification of bacteria deeper within the endometrium, or possibly a biofilm. The presence of lymphatic lacunae implies the stagnation of lymph with decreased lymphatic drainage suggesting that uterine clearance may be an issue. A recent study investigating the association of age and endometrial biopsy score with uterine fluid retention after insemination revealed increased age was associated with biopsy scores of IIB and III and that these groups had an increased incidence of fluid retention compared with I and IIA. This led to the conclusion that age was associated with fluid retention and that classification criteria for susceptibility to persistent breeding-induced endometritis is that the line between potentially resistant and susceptible mares can be drawn between biopsy scores IIA and IIB. Treatment using oxytocin and uterine lavage may therefore be beneficial in those mares. Endometrosis or chronic degenerative endometritis is a glandular and/or stromal fibrosis (scarring), including glandular alterations in fibrotic foci. Endometrial fibrosis is progressive and irreversible and tends to worsen with age. Degenerative changes may result from repeated inflammation from breeding and infection. The relationship of chronic degenerative endometrial disease with age and parity was investigated and found that maiden mares of increased age exhibited endometrial changes indicating that age alone will be a causative factor in the development of endometrosis. These authors also suggested that mares with an increased number of pregnancies had a higher incidence of poor endometrial quality.

Uterine blood flow is a dynamic process influenced by hormones, the presence of semen and pregnancy. Increased age and parity has also been demonstrated to influence the severity of uterine blood flow changes. Older maiden mares had a higher incidence of degenerative changes such as angiosclerosis or vascular elastosis than younger mares. Degeneration of the uterine vasculature seems to be strongly associated with increasing number of foals and is associated with decreased uterine perfusion below physiological levels found in normal mares. The importance of adequate blood flow and drainage of the uterus has been further substantiated with the use of Doppler ultrasonography, which has detected differences in uterine blood perfusion in mares with varying degrees of endometrial degenerative changes. Understanding and determining the underlying pathology present on culture, cytology, or biopsy enables the practitioner to identify the potential cause of subfertility in the mare. Using the appropriate treatments dictated by the results such as antimicrobials, anti-inflammatories, ecobolics, uterine lavage, mucolytics, buffered chelators, immunomodulators, as well as medications such as aspirin or pentoxifylline in mares with poor vascular perfusion and blocked lymphatics can aid in the resolution of subfertility in the mare.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Author declares no conflicts of interest.

References and Footnotes

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How to Use Endoscopy (Hysteroscopy and Laparoscopy) to Manage the Sub-Fertile Mare

Maria Schnobrich, VMD, DACT

1. Introduction

Endoscopy is the technique of using a rigid or flexible endoscope to visualize internal organs and structures. First described in the 1800s in humans, its use in veterinary medicine since the 1960s has enhanced diagnostic and surgical capabilities across species and disciplines. In the mare, the first report of endoscopy for reproductive purposes occurred in 1969 as an enhanced method of uterine evaluation and biopsy.1 Two methods of endoscopy used in reproductive evaluation and treatment of the mare will be discussed: hysteroscopy and laparoscopy.

The term hysteroscopy will be used to refer to passing the endoscope through the mare’s cervix to visualize the uterine lumen and associated structures (oviductal papillae, intraluminal cysts, and foreign bodies). Hysteroscopy has been used as an advanced means of evaluating uterine health (enhanced visualization, targeted biopsy of tissue) and treating pathology (uterine cyst removal, lesion debridement, oviductal hydrotubation, or flushing). Many authors have published previous articles on the use of hysteroscopy for reproductive tract evaluation and treatment and may refer to the procedure as examination of the uterus through video endoscopy and fibroscopy.2–4 In general, this procedure is not commonly used as part of a routine breeding soundness evaluation, given that most pathologies are identified with transrectal palpation and ultrasonography, endometrial cytology, culture and biopsy, as well as vaginal and cervical examination. Hysteroscopy is indicated in our practice when a known abnormality must be further characterized, when infertility has persisted (usually through one breeding season) without an identified cause despite aggressive management and normal findings on routine diagnostics, or when treatment via hysteroscopy is indicated. This article will focus on hysteroscopy as a means for identifying abnormalities and a more-detailed explanation of how to perform oviduct flushing or hydrotubation. Laser removal of cysts and foreign body removal has been previously described elsewhere and will only briefly be discussed.5

Laparoscopy (passing a rigid endoscope through a flank incision to visualize the reproductive tract in the abdomen) is used even less frequently as a method of reproductive tract evaluation and was first described in the mare in the 1970s as a method to evaluate ovulation.6,7 Flank laparoscopy has been used to identify, biopsy, or characterize abnormalities of the reproductive tract that lie within the abdominal cavity (adhesions, hematomas, abscesses, and neoplasia),8 or to treat abnor-
malities in structures accessible by this method (ovarian neoplasia, oviductal prostaglandin E2 (PGE2) application, adhesions). Laparoscopy is rarely indicated to identify and characterize lesions, given that most are identified by routine breeding soundness examination procedures, but can help in cases of remote adhesions, ovariectomy, and when oviductal treatment (PGE2 application) is performed. Only the procedure of PGE2 application will be described in detail here.

2. Materials

Hysteroscopy
A 1-m flexible videoendoscope, 1–1.4-cm in diameter, with a biopsy channel for instrument introduction is used most commonly and should allow access to the tips of the uterine horns. The video-endoscope should have a light source that illuminates well for adequate visualization and also the ability to insufflate the uterus. Prior to hysteroscopy, the endoscope and biopsy channel are disinfected with a sterilizing agent, according to the manufacturer’s instructions, and then rinsed copiously with sterile, distilled water. Any instruments that will be passed through the scope or into the uterine lumen (biopsy forceps, laser, guide wire, and tubing for oviduct catheterization) should be sterilized prior to use. The capability to record the procedure and store images is ideal, as well as a monitor that allows multiple people to view the real-time endoscopy to facilitate certain procedures.

Cyst Removal
Depending on the size of the cyst, either a biopsy tool or a laser (Nd:YAG or diode) can be passed through the channel of the scope for cyst removal. Diode lasers are used most commonly for uterine cyst ablation.5

Biopsy
Alligator endoscopy biopsy forceps, (160-cm length), are ideal for sample collection when evaluating focal lesions seen on hysteroscopy. Samples are placed in Bouin’s5 or 10% buffered formalin solution at a ratio of 1:10 for histomorphologic analysis or submitted for culture. Biopsy forceps have also been used to debride endometrial plaques or lesions, and the removed tissue can be submitted for culture and histopathology.

Foreign-Body Removal
Rat-tooth endoscopy grasping forceps, ≥160 cm length, which can be passed through the biopsy channel of the endoscope, are ideal for grasping and removing small foreign bodies.

Oviduct Hydrotubation
Thirty minutes prior to the procedure, the mare is administered ceftiofur crystalline free acid (6.6 mg/kg IM) and flunixin meglumine (1.1 mg/kg; IV). The materials required for oviduct flushing include a gas-sterilized 200-cm polyethylene tubing (1.7-mm outer diameter) with a 22-gauge catheter tip fitted and glued inside the internal tubing and extending approximately 1 cm from the end of the tubing (Fig. 1). A guide wire (0.46 mm diameter, 220 cm long, human angiocatheter guide wire) is placed through the tubing with the rigid end extended through the catheter tip. Sterile lactated ringer’s solution (20 mL) in a 20-mL syringe with a 20-gauge 1.5-in needle attached is used for flushing each oviduct via the introduced catheter.

3. Methods

Mare Preparation
The mare is placed in stocks and the tail is wrapped and deflected to the side. The mare is sedated approximately 5–10 minutes prior to the procedure. Dose of sedation is based on behavior of the mare, and detomidine HCl 0.01–0.02 mg/kg and butorphanol tartrate (0.01–0.02 mg/kg) are administered by intravenous route. Xylazine (0.2–1mg/kg) or detomidine HCl (0.006–0.01 mg/kg) is administered again if sedation is not adequate or if procedure length dictates

Fig. 1. Image of catheter tip, guide wire, and tubing used for oviduct flushing.
additional redosing. Transrectal palpation and ultrasoundography is performed to determine whether the mare’s cervix is tenable and appropriate for the procedure. Ideally, mares should be in mid-diestrus with a closed cervix to allow adequate insufflation of the uterus. If the cervix is relaxed it can be very difficult to maintain insufflation, and may be impossible to visualize the entire uterus or perform additional procedures (cyst removal, oviductal flushing). As much fecal material as possible is evacuated from the rectum, and the mare’s perineum including the vulva, clitoral fossa, and vestibule are aseptically prepared.

Personnel

Depending on the procedure performed, it is ideal to have three or four people present (not including mare restraint) to facilitate instrument and sample handling. One person (A) operates the endoscope (driver). One person (B) maintains position of scope at the level of the cervix, advancing and redirecting under the driver’s (A’s) guidance and prevents escape of air from the uterine lumen. A third person (C) is available as needed for instrument placement through the portal and sample handling. For oviduct flushing it helps to have a fourth person to expedite flushing, as described below.

Hysteroscopy Procedure

The operator (B) wearing a sterile sleeve and glove first “white balances” the videendoscopy for accurate visualization of tones and brightness. Sterile lubricant is applied to the back of the hand, and the endoscope is advanced into the vaginal vault. The cervix and vagina are evaluated, and then the endoscope is passed through the cervical canal. Once through the cervix, the uterus is insufflated with air so that the uterine bifurcation can be visualized. Mean pressures of 18–30 mm Hg are enough to facilitate visualization and pressures of 100 mm Hg, or overdistention should be avoided as mares become quite uncomfortable and damage to the uterus is possible.8 Sterile lactated ringer’s solution or sterile 0.9% saline can be used to dilate the uterus for evaluation in place of air and is often less irritating. It should be noted that aqueous solution for uterine distention makes visualization difficult when blood, mucus or exudate is present, and foreign body removal is more difficult in some cases. If the cervix is dilated sufficiently and insufflation is difficult, the fingers or entire hand can be passed through the cervix and then positioned in the opening to stop the efflux of air or fluid.

Orientation is achieved by allowing several drops of water to be expressed from the tip of the endoscope; the direction the water falls identifies the ventral position, allowing determination of the left and right horn. Once insufflation is achieved the endoscope is advanced into one of the uterine horns with continuous air being infused as needed to sufficiently dilate and visualize the entire endometrium of that horn. The lens at the tip of the endoscope may need to be repositioned or rinsed so that the view is clear and passes through the center of the uterine horn until the end of the uterine horn and oviductal papilla are viewed. Slow removal from one uterine horn is performed making sure to visualize 360° of the endometrium of the uterine lumen until the tip of the endoscope is returned to the bifurcation. The same procedure is repeated for the other uterine horn. The scope is then retroflexed upon itself so that the cranial aspect of the cervix and caudal uterine body can be examined. Following hysteroscopy, air is infused as the endoscope is withdrawn from the cervix, dilating the cervical lumen and allowing visualization of some cervical defects (adhesions, sacculations, diverticulums).

The effect endometrial cysts have on fertility is debated in the literature, but in some cases, based on size and location, they are believed to be potential detractors to normal uterine function (impede embryo motility in early pregnancy, or impair uterine clearance). Intraluminal cysts are removed at the base of the structure where the cyst wall meets the normal-appearing endometrium. Laser cyst removal/ablation has the advantage of reduced bleeding, although the smoke generated is irritating to the endometrium and mares often require at least one estrous cycle to recover from the procedure. Alternatively, when using laser cyst ablation, insufflation with sterile lactated ringers has been used successfully as well to minimize smoke irritation. If the cyst is pedunculated, biopsy forceps can be used to sever the base of the stalk, and the cyst can be removed entirely. Pedunculated cysts can be removed using electrocautery loops as well with minimal bleeding. Intraluminal adhesions can be broken down with a laser or biopsy forceps depending on the size and character of the adhesion. Foreign bodies identified during hysteroscopy are grasped with forceps through the biopsy channel of the endoscope and removed with the endoscope through the cervix, or removed with uterine lavage following hysteroscopy. Biopsy of areas of suspected pathology (plaques, mucoid debris) can be performed and submitted for culture and histologic evaluation.

Following hysteroscopy, the uterus is lavaged with sterile lactated ringer’s solution (1–3 L) or until the efflux is clear and 10 IU of oxytocin1 is administered IM to facilitate uterine clearance and allow the air to escape following insufflation. Transrectal palpation and gentle manipulation of the uterus can aide in expressing the remaining air or fluid from the uterine lumen. A luteolytic agent (PGF2α or cloprostenol) should be administered at the end of the procedure and follow-up treatment dictated by findings of hysteroscopy.

Oviductal Hydrotubation

Oviductal hydrotubation (cannulation and retrograde flushing of the oviduct) has been previously
described in detail by Inoue\textsuperscript{10} using a hysteroscopic approach. The procedure involves hysteroscopic identification of the oviductal papillae, catheterization, and retrograde flushing under moderate uterine distention. Specifically, the oviduct is visualized hysteroscopically as described above. Once the endoscope is within several centimeters of the oviductal papilla, the guide wire is advanced through the tubing approximately 0.5 cm and passed into the opening of the oviductal papilla by advancing the tubing and wire together (Figs. 2 and 3). Once the wire is firmly seated in the opening, the catheter tip attached to the tubing is advanced over the wire and gentle pressure is applied to hold it in place as the wire is removed rapidly. Once the wire is removed using sterile gloves, the 20-mL syringe is attached by seating the needle into the end of the tubing and slowly but firmly flushing the entire volume of sterile fluid through the tubing. Ideally, no fluid is seen flowing from the oviductal papilla, although small amounts are considered acceptable, excessive backflow requires repeating catheterization. Often there is an initial resistance when flushing, which often gives way to gentle pulsing pressure. If the pressure is too great, the fluid will flush out the oviductal opening, minimizing the likelihood of oviduct rupture. Once the fluid is flushed, the catheter tip is removed and the endoscope is repositioned in the opposite uterine horn to repeat the procedure on the contralateral side. The guide wire is replaced into the tubing during endoscope repositioning. Over insufflation of the uterus makes positioning and catheterization difficult as the uterine horns often contort and the angle of the opening of the oviductal papilla can be oblique. Changing the orientation of the oviductal papilla can be achieved by changing the position of the cervix (left, right, cranial, or caudal) while holding the endoscope in place. Following flushing of each oviduct, the uterus is lavaged as described previously. Transrectal ultrasound of the ovaries is performed, and air is often visualized around the ovary and infundibulum and can be useful to determine whether the flush was likely successful.

**Laparoscopy**

**Materials**

Routine preparation and instruments required for a flank incision is described elsewhere.\textsuperscript{11} An 11-mm diameter, rigid laparoscope cannula, a 10-mm diameter, 30-cm-long endoscope with 30° view, light source, and CO\textsubscript{2} insufflation capabilities are used for this procedure.

**Oviduct PGE\textsubscript{2} Application**

One tube (2.5 mL) of PGE\textsubscript{2} (0.5 mg of dinoprostone,\textsuperscript{10}) is divided as 0.25 mL volume per individual 0.5 mL sterilized embryo transfer straw with cotton plugs (two straws are used per oviduct). A sterilized embryo transfer Cassou gun with a stylet is used to dispense the gel.

**Procedure**

The mare is restrained in stocks and sedated. Potassium penicillin\textsuperscript{a} (22 000 IU/kg) and gentamicin sulfate\textsuperscript{a} (6.6 mg/kg) is administered IV 30 minutes prior to surgery. The flank region is clipped, aseptically prepared, and draped. The laparoscopic cannula and obturator are introduced into the abdominal cavity thorough the flank. The cannula is positioned midway from the ventral aspect of the tuber coxae and the last rib. The laparoscope is introduced into the abdomen and the abdomen is insufflated with CO\textsubscript{2} to 18 mm Hg. The reproductive tract within the abdominal cavity is evaluated for any abnormalities.
HOW TO TREAT THE SUB-FERTILE MARE

To place PGE₂ on the oviduct, the oviduct (located on the lateral aspect of the ovary, coursing through the mesosalpinx) is identified and approximately 1 mL of PGE₂ gel is dispensed liberally through the Cassou gun over the surface of the visible oviduct. The laparoscope and Cassou gun are removed and the incision is closed in a routine fashion. The procedure is repeated on the other side. Postoperative care includes NSAID administration for 5 days with stall rest and small paddock turnout. The mare can be returned to routine management 7 days after the procedure and live cover is considered safe within days following the procedure.

4. Discussion

In our practice, the most common use of endoscopy is for hysteroscopic evaluation of the uterus, lymphatic cyst ablation with laser and hydrotubation of the oviducts. Laparoscopy is used for advanced evaluation of the reproductive tract, ovariectomy, or PGE₂ application when hysteroscopic hydrotubation has been unsuccessful.

Hysteroscopic evaluation of the uterus is very useful in cases where the pathology cannot be identified by traditional means. Candidates for hysteroscopy include mares with persistent infertility despite aggressive and appropriate management, persistent infectious endometritis, or abnormal fluid patterns in the uterus or cervix on transrectal ultrasonography. Endoscopy in these cases has revealed intraluminal uterine adhesions (in one mare a complete horn had fibrosis extending across the entire opening of a uterine horn (Fig. 4), sacculations of the cervix or uterus that can serve as a chronic nidus for infection, and foreign bodies that were missed on routine evaluations. Interestingly, in our practice approximately 35% of mares that have hysteroscopy performed have an abnormality identified. Identification of these pathologies has helped define an appropriate treatment and management plan, and often leads to an improvement in fertility in mares that an abnormality is identified. In addition, finding no abnormality is helpful in narrowing the differential list for causes of infertility.

Cyst removal can often improve uterine clearance and in some mares seems to assist in future fertility. Most cysts do not interfere with embryo mobility and hysteroscopy is helpful in identifying those cysts which, due to their location and size may cause a problem, and also facilitates their removal through laser ablation.

Oviduct hydrotubation has been used in our practice over the past 2 years with moderate success. From 2014–2015 breeding seasons, 64% of treated mares (9 of 14) conceived in the same breeding season following treatment after most mares had been bred unsuccessfully three or more times prior to treatment. PGE₂ application of the oviducts is still used in our practice but due to cost and limited availability of PGE₂, hydrotubation has become the preferred method of oviduct treatment in the limited cases where this treatment is indicated.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References and Footnotes


*Olympus America Inc., 3500 Corporate Parkway, PO Box 610, Center Valley, PA 18034.*

*Boiun’s fixative solution, Sigma-Aldrich Corp., St. Louis, MO 63103.*
HOW TO TREAT THE SUB-FERTILE MARE

1 Buffered Formalin fixative solution, Sigma-Aldrich Corp., St. Louis, MO 63103.
2 EXCEDE, Zoetis, 100 Campus Drive, Florham Park, NJ 07932.
4 Hibiki Polyethylene Tubing, High Class grade, Size 5 Fr., Hibiki, Tokyo, Japan.
5 Nipro SAFELET Cath 22G x 1", Nipro Medical Corporation, 3-9-3 Honjo-Nishi, Kitaku, Osaka Japan.
6 Angiodynamics, Nit-Vu, High Performance Micro Guidewire, 300 cm, 0.41" Diameter. AngioDynamics, Inc., 603 Queensbury Avenue, Queensbury, NY 12904.
7 Dormosedan, Zoetis, 100 Campus Drive, Florham Park, NJ 07932.
8 Torbugesic, Zoetis, 100 Campus Drive, Florham Park, NJ 07932.
10 Oxytocin Injection, Bayer HealthCare LLC, Shawnee Mission, KS 66201.
11 PrepaDil Gel, Parmacia and Upjohn Co., New York, NY 10017.
12 Penicillin G Potassium, WG Critical Care LLC., Paramus, NJ 07652.
How to Manage Persistent Post-Mating Induced Endometritis

Etta Bradecamp, DVM, DACT, DABVP

1. Introduction

Post-mating-induced endometritis (PMIE), also known as post-breeding endometritis, persistent PMIE, and persistent post-breeding endometritis, is defined as the failure of the normal physiologic inflammation that occurs post-mating to resolve within 36–48 hours. Clinically, many of these mares can be identified by the presence of two or more centimeters of intrauterine fluid during estrous or between 3 and 36 hours post-breeding.1–3 Mares that suffer from PMIE have decreased pregnancy rates and increased early embryonic loss rates.4–6

A normal, transient inflammatory response occurs in all mares post-mating. In normal mares this inflammation peaks at approximately 6–12 hours and resolves by approximately 48 hours post-breeding.7 This inflammatory response is characterized by the influx of neutrophils and cytokines into the uterine lumen to aid in the phagocytosis of nonviable spermatozoa and bacteria combined with uterine contractions to expel fluid and debris from the uterus. Normal mares are also often referred to as resistant mares. In approximately 15% of mares the post-breeding inflammatory response remains elevated after peaking (> 8 h)8 In addition, some mares suffer from delayed uterine clearance either due to a larger, more pendulous uterus that hangs over the brim of the pelvis and/or poor myometrial contractility resulting in the accumulation of fluid within the uterus. These mares, known as susceptible mares, often retain greater than 2 cm of fluid within the uterine lumen for 24 or more hours post-breeding and have decreased pregnancy rates.

The uterine environment is very dynamic and must transition from an open system that is hospitable to semen and able to mount an acute inflammatory response to spermatozoa to rid the uterine environment of all foreign debris to becoming a closed quiescent organ that is ready to accept an embryo within 5–6 days. Post-breeding inflammation must be resolved by 96 hours post ovulation to maximize embryo survival.9

The introduction of spermatozoa, seminal plasma, extender, and bacteria at the time of breeding incites a cascade of inflammatory events. The removal of a large portion of the debris is via mechanical clearance; however, the innate immune system also plays a very important role in eliminating any foreign material from the uterus. Spermatozoa activate complement present within the uterine secretions. The cleavage of C5 to C5a and C5b triggers a chemotactic signal to polymorphonuclear neutrophils (PMNs), resulting in the influx of...
neutrophils into the uterine lumen.\textsuperscript{10} The activated PMNs bind to and phagocytose spermatozoa. Secondly, the activation of the PMNs results in release of prostaglandin from the cell membrane, which causes contractions of the smooth muscle of the myometrium. Removal of all debris from the uterus results in a decrease in the inflammation and return of the endometrium to its normal state.\textsuperscript{10}

In a normal uterus, the mucociliary apparatus and endometrial folds play an important role in the removal of debris from the uterus. It has been demonstrated that this normal architecture and ability to remove fluid and debris from the uterus is compromised in the susceptible mare. In a study performed by LeBlanc et al\textsuperscript{11}, methylene blue dye was infused into the uteri of both susceptible and resistant mares. Upon examination of the uterus at necropsy dye was found within the channels created by the endometrial folds in resistant mares. In the susceptible mares the dye remained pooled within the uterine body and there was loss of the distinct channels seen in the resistant mares.

In susceptible mares, also referred to as delayed uterine clearance mares, some failure in this normal inflammatory process occurs. One of a number of different scenarios possibly transpires in these mares. These scenarios include but are not limited to:

- The inability to modulate or turn off the inflammatory response once it is triggered, resulting in a persistent inflammation. Fumuso et al\textsuperscript{12} showed that after artificial insemination (AI) with dead sperm the post-breeding inflammatory condition persisted in susceptible mares until seven days post ovulation. In normal mares, this response is modulated within 8–12 hours and resolved by 36–48 hours.
- Poor mechanical clearance secondary to decreased myometral activity, disruption of the mucociliary apparatus or endometrial folds, cervical damage, vascular elastosis or lymphangectasia.
- Poor cervical dilation as seen in aged maiden mares or donor mares subjected to repeated embryo flushes over several years, or secondary to cervical trauma and fibrosis.
- A combination of poor uterine contractility resulting in the inability to clear debris from the uterus thereby continual stimulation of the inflammatory pathway leading to the accumulation of more fluid.

Mares that will develop prolonged post-mating endometritis may be difficult to identify prior to their first breeding. If the mare suffers from the inability to mechanically clear fluid from the uterus, this may be evident prior to breeding and give an indication to problems that may develop post-breeding. Oftentimes it is not evident that the mare is a susceptible mare until she is examined 24 hours post-breeding. The hallmark sign of a susceptible mare is the presence of greater than 2 cm of intrauterine fluid at this time.

The purpose of this paper is to describe the treatments for PMIE in mares where bacterial endometritis has been ruled out.

2. Treatment of Post-Breeding Endometritis

It is important to realize that when PMIE is recognized after the mare has been bred the first time, all treatments are attempted to modulate an inflammatory response that has gone awry. Figuratively speaking, “we are already behind the eight ball” as we attempted to modulate an inflammatory response that should have started down-regulating approximately 16 hours earlier. At this point, all attempts at treatment are to quiet down the immune system, help remove all of the inflammatory debris from the uterus, and aid in stimulating uterine contractions to prevent further accumulation of fluid within the uterus. There are four main components to treatment: modulation of the inflammatory response with steroids or other immunomodulators, uterine lavage to remove debris, ecbolics to aid in uterine contractility, and antibiotics if needed to prevent the development of a bacterial component in the compromised environment (Table 1).

3. Management of the Susceptible Mare to Prevent the Development of PMIE

Once a mare is identified as or suspected to be a susceptible mare, management is focused on preventing the development of PMIE. Studies have shown that treatment prior to breeding with corticosteroids in mares considered high risk is much more advantageous than waiting to treat 24 hours post-breeding. Mares treated prior to breeding had increased pregnancy rates compared with mares treated post-breeding.\textsuperscript{3} Secondly, given that the normal inflammatory response that occurs in mares starts to dissipate approximately 8 hours post-breeding, the implementation of a post-breeding lavage and ecbolics treatment 6–8 hours after breeding aids in clearing the fluid and inflammatory debris thus reducing the risk for further inflammation.

4. Corticosteroids (Dexamethasone, Prednisolone)

Administration of systemic steroids prior to breeding has been shown to aid in the modulation of post-breeding endometritis and improve pregnancy rates in susceptible mares. Bucca et al\textsuperscript{8} demonstrated that the administration of 50 mg of dexamethasone\textsuperscript{a} at the time of breeding in mares that exhibited four or more risk factors associated with PMIE resulted in improved pregnancy rates. However, if the administration of the dexamethasone was delayed until 24 hours post-breeding, no improvement in pregnancy rates was observed.\textsuperscript{2} This study demonstrates the importance of modulating the inflammatory response initiated by breeding and
the detrimental effects that it has when allowed to continue unchecked.

A study by Papa et al.\textsuperscript{13} also demonstrated an improvement in pregnancy rates of susceptible mares when prednisolone\textsuperscript{b} was administered around the time of breeding. Prednisolone, 0.1 mg/kg was administered orally every 12 hours for 48 hour prior to and post-breeding. Pregnancy rates significantly increased in susceptible mares treated with prednisolone from 0.0–64.5\%.\textsuperscript{13}

5. N-Acetylcysteine

N-acetylcysteine\textsuperscript{c} has both mucolytic and anti-inflammatory effects. It is impossible to separate the roles of these effects when administered. When administered intrauterine 24 hours prior to breeding to a group of mares that had not become pregnant after two to five cycles, LeBlanc\textsuperscript{14} achieved 85 percent pregnancy rates post treatment. There are two protocols for the administration of acetylcysteine. For mares that are known to be susceptible to developing PMIE it is recommended that 30 mL of acetylcysteine be diluted in 150 mL of saline and infused into the uterus 24 hours prior to breeding. Oxytocin (20 IU IV or IM) is administered 8 hours post infusion. If the mare is not treated prior to breeding and it is noted that the post-breed lavage is cloudy, infusion of 30 mL of acetylcysteine at the end of the lavage is beneficial. A uterine lavage is then performed 24 hours later and the nature of the efflux is evaluated.

<table>
<thead>
<tr>
<th>Medication</th>
<th>Dose</th>
<th>Route</th>
<th>Frequency of Administration</th>
<th>Indications for Use</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cloprostenol</td>
<td>125–250 mcg</td>
<td>IM</td>
<td></td>
<td>Induces luteolysis to facilitate return to estrus; also effective ecbolic</td>
</tr>
<tr>
<td>Dexamethasone</td>
<td>50 mg</td>
<td>IM</td>
<td></td>
<td>Administer prior to breeding for modulation of post-breeding endometritis</td>
</tr>
<tr>
<td>Dimethylsulfoxide (DMSO)</td>
<td>50 mL DMSO/L (900 mg/mL = 4.5% solution)</td>
<td>Intrauterine</td>
<td></td>
<td>Decrease mucus</td>
</tr>
<tr>
<td>Misoprostol (PGE\textsubscript{1})</td>
<td>Massage small amount on and into cervix 2–4 h before manipulation or intromission in nonpregnant mare</td>
<td>Topical on the cervix</td>
<td></td>
<td>Promotes cervical relaxation and dilation</td>
</tr>
<tr>
<td>Oxytocin</td>
<td>10–20 IU</td>
<td>IV, IM</td>
<td>Every 4–12 h</td>
<td>Post-breeding endometritis</td>
</tr>
<tr>
<td>Prednisolone oral suspension</td>
<td>0.1 mg/kg</td>
<td>Oral</td>
<td>Every 12 h</td>
<td>Modulation of post-breeding endometritis</td>
</tr>
<tr>
<td>N-acetylcysteine (20% solution)</td>
<td>30 mL of a 20% solution diluted in 150 mL of normal saline</td>
<td>Intrauterine</td>
<td>1–2 d before antibiotic infusion</td>
<td>Mucolytic</td>
</tr>
<tr>
<td></td>
<td>30 mL of a 20% solution diluted in 150 mL of normal saline</td>
<td>Intrauterine</td>
<td>Infuse 24 h prior to breeding followed by oxytocin injection (10–20 IU, IV or IM) 8–12 h after infusion</td>
<td>Anti-inflammatory</td>
</tr>
<tr>
<td></td>
<td>30 mL of a 20% solution diluted in 150 mL of normal saline</td>
<td>Intrauterine</td>
<td>Infuse into uterus after post-breeding lavage if lavage fluids are cloudy or if there was free-intra-uterine fluid after breeding Infuse 30 mL directly into uterine catheter; follow up with oxytocin injection (10–20 IU, IV or IM) 4–6 h later</td>
<td>Post-breeding therapy</td>
</tr>
</tbody>
</table>

\textsuperscript{AAEP PROCEEDINGS / Vol. 62 / 2016 177}
**6. Immunomodulators**

Several studies have demonstrated that the administration of *Mycobacterium* cell wall extract\(^4\) prior to breeding resulted in improved pregnancy rates in susceptible mares. Fumus et al\(^1\) showed that administration to susceptible mares at the time of artificial insemination resulted in uterine immunological changes similar to that found in resistant mares. Without immunomodulation the up-regulation of IL-1\(\beta\), IL-6, and TNF-\(\alpha\) persisted into diestrus in susceptible mares.\(^1,\)\(^12\) In a separate study, Rohrbach et al\(^1\) showed that mares diagnosed with persistent endometritis were more likely to become pregnant when treated with *P. acnes*\(^\circ\) compared with untreated mares, which were treated intravenously with *P. acnes* on days 0, 2, and 6. Treatment with *P. acnes* was most effective in mares bred between 2 days before to 8 days after the first treatment.\(^1\) It should be noted that there have been anecdotal reports of mares developing high fevers after being treated systemically with *mycobacterium* cell wall extract.\(^d\) Typically these fevers resolve in several days with medical treatment.

**7. Autologous Conditioned Serum/Platelet-Rich Plasma/Mesenchymal Stem Cells**

The ability of intrauterine infusions of autologous conditioned serum\(^\circ\), platelet-rich plasma\(^\circ\), or mesenchymal stem cells\(^\circ\) to modulate the expression of inflammatory cytokines and increase pregnancy rates of treated mares affords the veterinarian with yet another modality to treat PMIE. Reghini et al\(^1\) showed that the intrauterine infusion of platelet-rich plasma (PRP) into susceptible mares 4 hours post-breeding reduced the post-breeding inflammation when measured as the percent of neutrophils in uterine cytology, uterine fluid nitric oxide concentration and uterine fluid accumulation. In another study by Metcalf, susceptible mares treated intrauterine with PRP had a lower incidence of delayed uterine clearance and improved pregnancy rates than untreated mares (67 vs 19% in untreated mares).\(^1\)\(^7\) Other biological agents that have been shown to be beneficial in the modulation of inflammation include autologous conditioned serum and mesenchymal stem cells.\(^1\) When administered intrauterine around the time of breeding in normal mares both autologous conditioned serum and mesenchymal stem cells reduced the number of neutrophils within the uterine lumen 6 hours post-breeding. These treatments may also prove to be beneficial in mares susceptible to PMIE.\(^1\)

**8. Uterine Lavage**

Removal of dead sperm, bacteria, and inflammatory debris from the intrauterine environment is crucial to modulation of the post-breeding inflammatory response. Lavage can be performed as early as 4 hours post-breeding to aid it the treatment of PMIE. It is recommended that the uterus be lavaged repeatedly with 1–3 liters of saline or lactated Ringer’s solution until a clear effluent is obtained.\(^6,19\)\(^–\)\(^24\) Uterine lavage may need to be performed for more than 1 day and can be carried out to 3 days post ovulation.

**9. Ecbolics (Oxytocin, Cloprostenol)**

Due to delayed uterine clearance and the abnormal accumulation of intra-uterine fluid in susceptible mares, the use of ecbolics is paramount to treatment of PMIE. The administration of oxytocin\(^\circ\) (10–20 IU, IV or IM, every 4–12 h) or cloprostenol\(^\circ\) (250 \(\mu\)g IM once) has been shown to improve pregnancy rates when administered post-breeding.\(^21\)\(^,\)\(^22\) Several studies have shown that administration of cloprostenol after ovulation can have an effect on corpus luteum (CL) function and fertility; therefore, its use should be limited to prior to ovulation. Administration of cloprostenol greater than 12 hours after ovulation has been associated with decreased progesterone levels and administration greater than 2 days post ovulation has been associated with decreased pregnancy rates. For these reasons administration should be limited to estrus and no greater than 12 hours post ovulation.\(^25\)\(^–\)\(^27\)

In mares that suffer from poor uterine clearance due to poor cervical dilation the administration of misoprostol or N-butylscopolammonium\(^k\) to the cervix may aid in softening and dilating the cervix. This product can be applied to the cervix 1–2 hours prior to breeding or immediately following the post-breeding lavage to aid in uterine clearance. Manual dilation of the cervix at the same time is also beneficial. The utilization of these modalities to dilate the cervix in conjunction with the administration of ecbolics may result in more effective clearance of uterine fluid.

Some mares that have developed a severely pendulous uterus may continue to be unable to clear uterine fluid even with uterine lavage and the administration of ecbolics. Uteropexy, a surgical procedure in which the uterus is lifted and sutured dorsally to reposition it in a more normal horizontal position, is beneficial.\(^28\)

Although there are no scientific studies demonstrating the effectiveness of acupuncture on uterine fluid clearance, some practitioners believe it is beneficial in some susceptible mares. Acupuncture is a treatment modality that can be used to potentially aid in uterine fluid clearance.

**10. Reducing or Limiting the Number of Covers or Inseminations**

Mares that are identified as susceptible to developing PMIE should be managed so that breeding is limited to only once per cycle. Research has shown that each subsequent breeding results in a more pronounced inflammatory response than the prior one, reinforcing the importance of minimizing the number of inflammatory insults the uterus suffers.\(^29\)
11. Role of Seminal Plasma in Modulating Inflammation

Seminal plasma plays an important role in modulating the endometrial inflammatory response elicited by breeding\textsuperscript{30,31}. When semen is processed by centrifugation for cooled shipment or for cryopreservation, the percentage of seminal plasma in the breeding dose is greatly reduced. Therefore, in some mares, the inflammatory response to the inseminated that had some or all of the seminal plasma removed is much more pronounced. In most cases there is no option to have seminal plasma added into the dose of semen being used. However, it is important to recognize the role seminal plasma plays in the development of PMIE, especially in the susceptible mare.

12. Conclusion

When managing a mare with a history of PMIE, it is critical to treat the mare prior to breeding and in the 6–8-hour post-breeding time period in an attempt to minimize and modulate the inflammatory response before it becomes persistent. Numerous studies have shown that treatments that prevent the development of PMIE are highly successful in improving pregnancy rates in susceptible mares. Research has also demonstrated that if treatment is delayed until 24 hours post-breeding, no improvement in pregnancy rates is observed. The most difficult cases are mares that are being bred for the first time or their breeding history is unknown. If PMIE is not identified until 24 hours post-breeding, treatments should be initiated at that time to remove the fluid from the uterus and modulate the inflammatory response. If the mare does not become pregnant on that cycle then treatments to minimize and modulate inflammation should be employed proactively on the subsequent cycle.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

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How to Collect and Ship Ovaries for Oocyte Harvesting and Embryo Production

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1. Introduction

As equine veterinarians, we are all too familiar with untimely patient death. Although we spend our careers attempting to avoid it, situations will arise that are out of our hands and devastating for horse owners. Reasons for euthanasia of older horses (≥ 15 y) have been ranked in the United Kingdom as follows: lameness, colic, chronic illness, acute illness, laminitis, fracture, and other.1 In a retrospective study performed on a younger population of athletic Swedish Warmbloods, causes of their death or culling included (in order of prevalence): problems with the musculoskeletal system, accidents, respiratory system disease, digestive system problems, hoof, circulatory system, tumors, reproductive tract, urinary system, infectious diseases, miscellaneous, and unknown.2 As evident in these surveys, untimely death for a young or aged mare can happen because of various etiologies and occasionally before there is opportunity for her to reproduce. The field of equine reproduction has advanced within the past decade allowing horse owners the opportunity for propagating important genetics long after their equine companion is no longer living.

Obtaining successful pregnancies through oocyte harvest from mares that have died or been euthanized was first reported through the use of oocyte transfer and later intracytoplasmic sperm injection (ICSI).3,4 Historically, traditional in-vitro fertilization techniques have been unsuccessful in the horse, thus driving the implementation of assisted fertilization through ICSI, which is now well established within the industry. In recent years advancements have occurred to improve specific media and culture methods for sperm-injected equine oocytes to achieve an acceptable in vitro blastocyst rate, which has allowed ICSI to gain particular popularity with horse breeders.5,6 The use of sperm injection for oocytes collected from postmortem ovaries was first published in 2012 with ICSI-produced blastocysts being transferred into recipient mares through a transcervical approach.4 This is now the technique most commonly used by laboratories offering this procedure to try and provide a successful pregnancy from a deceased mare. The purpose of this document is to describe the process of submitting postmortem ovaries to make it as seamless as possible for referring veterinarians and horse owners interested in this procedure.

2. Materials and Methods

Cause of Death

Time is of the utmost importance when a mare dies unexpectedly. Retrieving the ovaries from the
mare as soon as possible is recommended although delays of up to 5 hours following death have been reported with successful production of foals; however, this particular mare was placed in a cooler immediately following euthanasia. Obtaining the oocytes from the deteriorating environment of excised ovaries should also be performed as soon as possible. Research has suggested that oocyte harvesting less than 6–8 hours after the mare’s death results in the most favorable outcome for pregnancies carried to term. Occasionally a mare’s euthanasia is planned, which allows the practitioner the opportunity to coordinate her cycle to the best of her ability. We generally recommend that a mare be in late diestrus or early estrus to maximize the amount of follicular activity available on her ovaries, but the total number of oocytes collected is heavily dependent upon a variety of details.

Ovary Removal and Packaging

Although many pregnancies have been obtained from ovaries collected from a mare humanely euthanized with a barbiturate overdose, the effects of these drugs upon the oocytes are still not fully understood. In one retrospective study, foals were reportedly produced from oocytes collected from mares euthanized through various means including inhalant anesthesia, a barbiturate overdose, and ovary removal under injectable anesthesia just prior to euthanasia. Oftentimes the particular situation will dictate the best method available for humane euthanasia.

Removal of the ovaries is a fairly straightforward technique, which can easily be performed in a field setting in lateral recumbency. Both ovaries are usually obtainable from one side/incision negating the need to roll the horse over to the other side. At our facility, we perform this procedure wearing nonsterile palpation sleeves with an examination glove on each hand. It is not necessary to maintain surgical sterility, but asepsis is advised. Once in lateral positioning, make a 15-cm longitudinal skin incision along the flank halfway between the last rib and the point of the hip (Fig. 1). Continue this incision through both the external and internal abdominal oblique muscles. Once the incision is through the muscle layers, use a gloved hand to bluntly puncture through the peritoneum entering into the abdominal cavity, being careful to avoid puncturing bowel and possibly contaminating the ovarian surface. Ideally, locate the ovary contralateral to the incision first by palpating over the dorsal surface of the uterine body and following the uterine horn. Oftentimes the location of this ovary does not allow for complete visualization and blind dissection with a pair of surgical scissors may be necessary. Once the contralateral ovary has been removed, the ipsilateral ovary should be located easily and often can be completely seen through the incision (Fig. 2). Once removed, rinse both ovaries with room temperature embryo flush solution, saline...
HOW TO TREAT THE SUB-FERTILE MARE

(0.9% NaCl), or lactated Ringer's solution and place within a secure plastic bag with a small amount of the same fluid to keep the tissue moist during transport.

Logistics

When a person uses the phrase, “the devil is in the details,” it does not begin to describe the process of coordinating logistics behind timely ovary transport, and it can often deter a practitioner from offering this service. There are several different options available, and having a plan in place prior to an emergency situation will ensure the smoothest transport possible. Universities, large practices, or any private practitioner with known clientele interested in this option should establish this plan of action in advance of actually implementing it.

Prior to arranging shipments, the receiving facility should be contacted and timing coordinated. The ovaries must arrive at a time when the receiving facility can prepare a team to harvest the oocytes and perform ICSI at 24–30 hours later during the following day. This timing might vary with facility and time of year.

If the laboratory offering postmortem ovary processing is within driving distance, that is often the best option. Generally it is recommended to ship these ovaries at body temperature (~37°C) but only if the transport time is within an hour. This can be achieved by using a thermoprotective container with warmed bags of 1 L saline surrounding and protecting the ovaries.

If the mare has a chronic ailment whereupon humane euthanasia can be coordinated, ovaries sent via FedEx or UPS next day delivery provide a reliable method for reasonable shipping intervals and arrival times. Organizing the procedure toward the end of the day but allowing time for removal and packaging will allow for the shipment to be one of the last packages picked up for the day. By choosing next-day delivery with the option of first in the morning drop-off service, the ovaries can be processed approximately 12–14 hours after the mare has been euthanized.

More often than not, shipping ovaries via counter-to-counter method is the best available option for a rapid transit time to their destination. A plane flight must be organized and direct flights are heavily recommended, given that ovaries are notorious for missing their connecting flight. In this post-9/11 era, shipping tissue specimens is not an easy task and long gone are the days of just pulling up to a commercial cargo office to quickly send specimens. If you are affiliated with a group that commonly ships semen you are likely a “known shipper” through the Transportation Security Administration and much of the legwork has already been performed. Typically, a receptionist or office manager already savvy in organizing shipments will choose the flight based on the airline you have an account with, fill out the air bill information, and arrange a courier to transport. If you belong to a practice that has not established this service yet but will routinely use and are interested in it, be sure to begin the steps of becoming a “known shipper” as far in advance as possible, given that it will take a few months to establish an account with an airline. It is possible for a solo practitioner to ship ovaries on a “one-up shipper” emergency basis without previous experience by personally escorting the container to the cargo service of an airline once a flight is chosen. As the person responsible for the contents of the shipment, you are required to present one government-sanctioned form of identification or two forms of other identification and fill out a daunting amount of paperwork to vouch for the safety of your shipment. This may take several hours of preparation and will likely cause delay in a process that is extremely time dependent.

To avoid many of these delays, various nationwide courier companies are available, maintain “known shipper” accounts with many airlines, and will complete a large portion of the paperwork ahead of time. To identify a courier in a certain area, a simple Internet search for the term “courier” servicing the airport closest to your location will often yield results. Everything comes with a price though, and each step along the route will cost an additional amount when handled by a third party. It is important to weigh all of the variables in these situations to determine the best course of action for potential success.

Finally, if finances do not provide a significant hurdle, several chartering companies offer emergency transport of items 24 hours a day, 7 days a week. Air transportation services such as UPS Express Critical or Sonic Delivery will provide expedited same-day delivery of items both for domestic and international locations. These services are frequently used by human hospitals for transport of organs across the country and may provide a useful service for transporting ovaries from a very valuable mare.

Packaging

It is extremely important to avoid large temperature fluctuations during transportation, which places an emphasis on the importance of appropriate shipping containers. If possible, attempt to plan ahead while maintaining an awareness of the ambient temperatures that change throughout the course of travel. Extremely hot periods of the year can prove catastrophic if a container is required to wait on a tarmac for a lengthy period of time. If transport takes longer than a few hours, ship the ovaries at room temperature (~22°C), although during particularly hot months or extremely prolonged transport, shipping them slightly cooler may be beneficial. It is not recommended to cool the ovaries below a cool room temperature or placing them on ice, given that this could have an effect on pregnancy success.7
Providing a consistent environment can be achieved by using a shipping container intended for semen. A passive cooling device with the coolant cans removed, a cooler insulated container, or a simple Styrofoam box with added layers of insulation are viable options. A couple of 1-L bags of room temperature saline can be added to provide protection and help to stabilize the ambient temperature. Ideally, a thermoregulating portable incubator could be set to an ultra-precise temperature and maintain a reliable environment for shipping postmortem ovaries. Newer units of this incubator offer the convenience of setting the two separate chambers within the device at different temperatures. This device would be very useful in a practice offering postmortem oocyte extraction or additional assisted reproductive procedures.

Stallion Choice
Finally, a key step to consider from the very beginning of this process is stallion selection and semen shipment. Although equine oocytes have been successfully cryopreserved and foals have been produced, the efficiency is not high. Therefore, we recommend fertilization of the collected oocytes by ICSI, even if the embryos are to be cryopreserved. Consequently, a stallion or stallions must be selected for sperm injection. If the collected oocytes successfully mature, sperm will be needed for ICSI by approximately 24 hours after oocyte harvesting. If possible, frozen semen should be organized to arrive either with the ovaries or the following day. We often recommend two straws, to allow one for a backup, but this may need to be adjusted based on the specific straws. Cooled/shipped semen may offer better results and can be collected the day of ovary arrival and shipped to arrive the next day, prior to the sperm injection procedure. A limited amount of cooled semen is needed. One advantage for ICSI is that a mare owner may choose more than one stallion to inject individual oocytes; however, we generally do not recommend picking more than two stallions. Although the ICSI procedure uses minimal amounts of sperm, good-quality semen from which to select sperm for oocyte injections is still essential for optimal results.

Available Facilities
As of today, there are two main facilities within the United States and a facility in Europe with published results, offering commercial postmortem ovary processing with an ICSI procedure. Colorado State University and Texas A&M University have had the longest running programs and have been paramount in conducting research that has led the way to successful pregnancies and foals born from oocytes collected from postmortem ovaries, and a similar program is available for the European community. More facilities are offering the oocyte harvesting aspect of excised postmortem ovaries and will subsequently ship the oocytes to a facility offering ICSI services. Location within the country should dictate which facility is chosen, given that the race against time is a big factor toward success.

3. Results

What to Expect
Although beyond the scope of this article, below is a brief overview of the overall process as previously described. Upon arrival, the temperature is immediately checked within the fluid surrounding the ovarian surface and recorded. The ovaries are then rinsed with warmed saline or a complete embryo flush medium to gently remove potential organic debris. The surface of the ovary is examined and loose parenchyma and remaining oviductal tissue is removed to facilitate easier access to palpable follicles. Palpable follicles are incised with a scalpel blade and the follicular fluid collected within a petri dish. The interior of each follicle is carefully scraped with a bone curette of a size proportional to the follicular dimensions (Fig. 3) to physically detach the cumulus oocyte complex, which has unique anatomical features and a tight attachment to the follicular wall. After each visible follicle has been processed, the ovary is sliced into sections to expose any additional follicles for scraping. Although time consuming, this procedure has provided the best method to collect complete cumulus oocyte complexes that result in competent oocytes for ICSI.

The most optimal scenario for success is when a practitioner is comfortable with the process of harvesting oocytes from postmortem equine ovaries prior to shipping. Once obtained by the practitioner, immature oocytes can be placed within a suitable holding medium. One such published medium is 40% M199 containing Hank’s salts and HEPES, 40% M199 containing Earle’s salts and 20% fetal bovine serum, and 25 ug/mL gentamycin (EH medium), which can be maintained at room tempera-
However, not many equine facilities commonly stock these media in their practice. At the American Association of Equine Practitioners Annual Conference in 2014, similar blastocyst rates were obtained when the EH medium was replaced with a commercial complete embryo holding solution for the purpose of holding immature oocytes and could provide an alternative method for general practitioners. Once collected, the immature oocytes can be placed in either a 2-mL Nalgene cryogenic tube or 1-mL borosilicate glass vial filled with the chosen medium and maintained at room temperature, taking care to minimize air within the tube. It is recommended to wrap the lid with plastic paraffin film as extra security against leakage during transport. This container should then be placed into a larger container, such as a conical tube, also filled with the same media with the lid wrapped in plastic paraffin film for extra leakage prevention. These immature oocytes can then be sent in a portable incubator set at approximately 22°C, a passive cooling device with the coolant cans removed to maintain stable room temperature or an immature oocyte specific container. This technique could provide an alternative method for equine practitioners, adept at postmortem oocyte harvesting, for shipping the oocytes to a laboratory offering ICSI and reduce the stress affiliated with emergency ovary shipment.

The number of oocytes that can be collected per mare is variable and primarily depends on the number of follicles present on the ovaries. When oocytes were collected from mares of various ages and reproductive activity, an average of 11 oocytes were collected per mare. However, in our laboratory, we have collected as many as 30 oocytes from the occasional mare, and no oocytes from mares with no follicular activity. In general, approximately half of recovered oocytes will mature in vitro and proceed to ICSI. Of that cohort, approximately half of the early embryos will continue to develop into quality blastocysts worthy of nonsurgical embryo transfer. Many factors will affect these projections, some of which include mare age, duration and severity of illness, quality of semen, environmental factors, and shipping conditions.

4. Discussion
Offering postmortem ovary extraction and shipment to a laboratory established in equine ICSI can provide an important avenue for practices with clientele interested in the procedure (Fig 4). As mentioned throughout this article, time is one of the most important factors toward the success of this procedure. Preparing supplies and enacting a plan before the emergency phone call can also make a significant difference. If a practitioner is comfortable and has previous experience in scraping and processing postmortem equine ovaries, shipping the oocytes to a laboratory with ICSI capabilities is the most ideal.
scenario. Several facilities across the contiguous United States offer this service and ICSI-produced embryos can often be transferred into a recipient mare at that facility, transported to another facility for transfer closer to the owner, or vitrified for transfer at a later date. Between the advancement in reproductive technologies, the widening availability, and success at various locations, horse owners should understand that they have the opportunity to preserve important genetics for future generations in the face of a catastrophic event. This paper is intended to provide enough details for a practitioner to feel comfortable in the removal and shipment of ovaries from a deceased mare to offer this procedure to interested clientele.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

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How to Interpret pH Profiles of Mammary Gland Secretions to Predict Imminent Parturition in Mares

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1. Introduction

Although large broodmare farms have the advantage of around-the-clock staff monitoring foaling mares, the majority of horse owners foaling one or few mares have limited resources when it comes to foaling management. Mares are notorious for variable gestation lengths, and may foal normally as early as 320 days or after more than 365 days.1 Given that the majority of mares (83%) foal out between 6:00 p.m. and 6:00 a.m., usually between 9:00 and 11:00 p.m. or 2:00 and 6:00 a.m. (Fig. 1),2 owners may spend many nights monitoring a mare before she foals.

Traditionally foaling managers track physical changes in the mare to determine when parturition is imminent. Many mares will “bag up,” or show mammary development in the weeks before foaling. Hormonal changes such as an increase in relaxin lead to relaxation of the pelvic ligaments, and elongation and softening of the vulva, which also signal impending parturition (Fig. 2). Typically, mares will also “wax,” or show precolostral secretion accumulation on their teats in the hours to days before foaling. Unfortunately, multiparous mares may show some of these changes more than a week before foaling, and maiden mares may show almost no changes, or change very suddenly before foaling.

The electrolyte composition of mammary secretions has been used to monitor for impending parturition in mares carrying normal pregnancies for years.3–6 A decrease in sodium, increase in potassium, and increase in calcium and magnesium have all been dem-
onstrated to be useful parameters to predict fetal development and the onset of parturition. More recently, a study out of Japan demonstrated a decrease in pH from mammary-gland secretions immediately before foaling, and a second study out of central Kentucky confirmed these findings and showed an association between mammary-gland electrolytes and pH. Since those two studies came out, we have incorporated the assessment of pH from perfoaling mammary secretions into our clinical foaling program the past 3 years and have found it to be a reliable method to predict impending parturition. We have observed three particular trends in pH changes/profiles in mares in clinical practice, and here describe our experiences and present some novel unreported patterns for the pH profile in normal perfoaling mares. In addition, we also discuss various methods to determine pH and associations between pre-foaling electrolytes of the mammary gland and pH. Our overall objective is to provide a clinical paper to allow other equine practitioners to effectively use pH to monitor normal periparturient mares.

Mammary-Gland Electrolytes in Pre-Foaling Mares

As mammary-gland development progresses, pre-foaling secretions increase. These secretions initially are rich in sodium (~100 mg/dL) and chloride (~100 mg/dL) and poor in calcium (5–10 mg/dL), magnesium (2–5 mg/dL), and potassium (< 10 mg/dL). Closer to parturition, the pre-foaling secretions become richer in calcium (40–50 mg/dL), magnesium (30–40 mg/dL), and potassium (40 mg/dL), and poorer in sodium (20 mg/dL) and chloride (20 mg/dL). Most mares present an inversion in the concentrations of sodium and potassium in the 1–2 days before foaling. At the same time, mammary secretions change from a clear to yellow serous secretion to a thicker, cloudier, whiter secretion.

A seminal study out of England assessed changes in mammary-gland electrolytes and described a sodium and potassium inversion, with potassium levels increasing, and sodium levels decreasing before foaling (Fig. 3). However, this inversion is not consistently seen in all mares, and is highly variable. Protein, lactose, and calcium also increase pre-foaling, and calcium carbonate (CaCO₃) has been shown to be both a specific and sensitive predictor of foaling within a 72-hour period, given that CaCO₃ increases dramatically in the normal mare before foaling. Work by Ley and collaborators suggests that mares with a CaCO₃ less than 200 ppm are unlikely to foal within 24 hours. The kit tested by Ley and collaborators, and similar kits measure calcium carbonate by a reaction with a zinc salt and a color indicator (zincon). These kits have been popular in North America for years for monitoring one or few foaling mares.

The commercial kits available are considerably expensive, especially when monitoring multiple mares, and require at least 0.5–3 mL to allow accurate assessment of calcium carbonate. Unfortunately, some maiden mares may provide only a few microliters of mammary-gland secretion, and some mares may foal unnoticed if the observer is not testing the secretions. Commercial water hardness strips are available as a cheaper and effective method of estimating calcium in mammary secretions. These test strips detect calcium and magnesium that form a complex with disodium ethylenedinitrilo tetraacetic acid and causes a change in strip color from green to violet. The strips contain four or five squares, and concentrations are estimated from the number of squares that change.

Fig. 2. Classic physical changes in a periparturient mare close to parturition. On the left, a pronounced mammary gland is noted, in the center picture, the examiner is holding the dorsal aspect of the labia to demonstrate vulvar softening and elongation. On the right, the examiner is palpating a hollow depression on either side of the base of the tail.

Fig. 3. Electrolytes (sodium, potassium, and calcium) concentrations in a normal periparturient mare in the days leading up to foaling.
colors. However, given that the strips measure magnesium as well as calcium, results may be less accurate than the test kits as magnesium also gradually increases in milk secretions pre-foaling.5 Calcium carbonate levels have been incorporated into the criteria that most clinicians utilize if deciding to induce parturition in mares. Two studies out of Italy have demonstrated the usefulness of measuring calcium and then administering low doses of oxytocin,11,12 and clinicians have incorporated milk calcium levels as one criterion to help assess when induction of parturition will result in a viable foal.4,13,14 Some clinicians, when presented with a situation in which induction of parturition is warranted, are comfortable inducing a mare when the mare meets the following criteria: soft and relaxed cervix, at least 320 days of gestation, and mammary-gland secretions with calcium carbonate of 200 ppm. A recent study out of New York14 incorporated the presence of acidic mammary-gland secretions (pH ≤ 6.5) into their foaling induction criteria with apparent success.

Mares with placental pathology exhibit abnormal electrolyte profiles; thus, electrolytes are not reliable in these mares.15 At this time, we do not have enough data to provide meaningful information on pH values in cases of abnormal placental pathology. It is our clinical impression based on a small number of cases (~10 clinical cases) that pH does change during times of fetal stress or impending abortion.

2. Materials and Methods

Obtaining the Sample and Methods for Determining pH

The first time pre-foaling mammary-gland secretions are collected from a mare can be a challenge for certain patients. Most mares will display signs of discomfort by swishing the tail up and down and kicking at the operator. To safely milk a mare, one experienced handler should restrain the mare’s head. In fractious or nervous mares intolerant to the procedure, a lip chain may be warranted. The authors recommend approaching the mare from the left side, placing the left hand on the mare’s hip while the right hand slowly touches the ventral aspect of the abdomen. Some mares may become too dangerous; therefore, the practitioner may opt to sedate the mare for the first time until the mare is used to being touched. Before milking a mare for the first time, it is advisable to clean the two udder halves with warm cotton and dry with a paper towel. We prefer to milk the mare using a conical 50-mL tube or a disposable Dixie cup. We prefer to hold the tube or cup with three fingers and milk the mare...
with the thumb and index finger (Fig. 4). Following collection, the milk sample should have the pH assessed by one of the methods described below. It is unknown for how long after collection pH can still be accurately assessed; thus, we recommend measuring pH within 15 minutes.

Determining pH with test strips has the advantage that strips require minimal secretions. This is particularly useful for maiden mares that have very small amounts available to be tested, even on the day of foaling. Overall, pH meters are more accurate than most pH strip tests; however, pH meters are more expensive and oftentimes not readily available, or easily broken in ambulatory practices (Fig. 5). If the practitioner elects to use pH strips over pH meter, the strips should have a pH range from 5.5 to 8 units, and have readings with increments of 0.1 or 0.2 units. Unfortunately, commonly available pH strip tests usually read in increments of 0.5 to 1 unit of pH. These strips are not accurate enough to detect the slight changes needed to determine impending parturition. Some test strips\(^a\) (Fig. 5A), have been shown to be highly \((r = 0.93)\) and significantly correlated with pH meter\(^5\) and are suggested for use by the authors.

There are several pH meters on the market. One company has a meter\(^b\) coupled with a small microconvex electrode allowing determination of very small quantities; however, this meter is more expensive and probably best used for research rather than clinical practice (Fig. 5B).\(^5\) The meter currently used by the authors is a relatively cheap handheld meter designed for testing water pH (Fig. 5C). Before each reading, the meter is calibrated to a pH 7 standard, and then rinsed thoroughly with distilled water, and tapped dry. Approximately 500-1000 \(\mu\)L of mammary-gland secretion is then placed in the sample well, and the pH of the secretions are measured. After measurement, the pH meter is again thoroughly rinsed with distilled water and allowed to dry.

### 3. Results

#### pH Profile

Normal prefoaling secretions have a pH of 8.0–8.5 that then decreases in the weeks to days before foaling from 8.0 to 7.5, and eventually to 6.5 or lower at time of foaling. Based on our experiences over the past 3 years using pH of the mammary gland-secretions in approximately 100 mares (Thoroughbreds, Standardbreds, Quarter Horses, Warmbloods, and a number of mixed-breed mares, age 4–23 yrs), we have been able to identify three profiles as described below.

**Pattern 1**

In our experiences, we observe this pattern most commonly in maiden and young broodmares. Mares presenting with this pH pattern may show discrete to no mammary-gland development until 24–48 hours before parturition, when sudden mammary-gland development and a decrease in pH. These mares will foal within the first 24 h that pH turns acidic.

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\(\text{Fig. 6. Pattern 1 (Fast pH reduction). This is most commonly observed in maiden and younger broodmares. It is characterized by a fast decrease in pH from a slight alkaline pH (e.g., -7.5) to a slightly acidic pH (e.g., 6.5–6.8). These mares may not have any expressible mammary-gland secretions before sudden mammary-gland development and a decrease in pH. These mares will foal within the first 24 h that pH turns acidic.}\)

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**Pattern 1 - Fast pH reduction**

![Pattern 1 - Fast pH reduction](image)

**Fig. 6.** Pattern 1 (Fast pH reduction). This is most commonly observed in maiden and younger broodmares. It is characterized by a fast decrease in pH from a slight alkaline pH (e.g., -7.5) to a slightly acidic pH (e.g., 6.5–6.8). These mares may not have any expressible mammary-gland secretions before sudden mammary-gland development and a decrease in pH. These mares will foal within the first 24 h that pH turns acidic.

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**Fig. 7.** Classic sodium potassium inversion in mares presenting pattern 1. Na\(^+\) And K\(^+\) concentrations in mmol/L ± SEM.
to slightly acidic in the next day (e.g., 6.6–6.8), with mares usually foaling that night (Fig. 6). Based on our experiences, this type of mare will show the classic sodium/potassium inversion before foaling as described by Ousey and others, and an associated decrease in milk pH, increase in calcium and magnesium, and reduction in chloride (Figs. 7 and 8). These mares may decrease from a pH of approximately 8 to slightly alkaline pH of 7.5, and then below 7.0 at time of foaling. Mares that drop very rapidly (by \( \frac{0.5}{24} \) h) may be 7.0 in the morning, and be 6.5 or lower at foaling that night.

Pattern 2

In our clinic, most mares following pattern 2 are older multiparous broodmares or older maiden mares carrying a foal for the first time (e.g., 15–23 y). These mares do present mammary-gland development several days before parturition, and may have mammary secretions with elevated calcium several days before they finally foal. These mares may exhibit a sodium/potassium inversion and an associated decrease in milk pH, but do not foal for several days to weeks after an acidic pH has been achieved. These mares will decrease to 7.5, and then below 7.0, and gradually decrease to below 6.5, and may not foal for a week afterward, or until the pH is 6.2 (Fig. 9). These mares also seem to present more problems such as dysmature foals, dummy foals, and slow foals. In our clinical experience, these mares may be the ones having dysmature foals or other peripartum complications, but we also have observed several normal mares presenting this pattern.

Pattern 3

This is a very uncommon pattern for pH. Mares in this category will foal with high and alkaline pH (7.5–8) (Fig. 10), will not exhibit a sodium/potassium inversion in mammary secretions (Fig. 11), and secretions maintain a low calcium and magnesium and high chloride. This pattern may be observed in older or younger mares and it does not seem to be associated with other problems, given that foals born from these mares are reported to have normal passive transfer of maternal antibodies through colostrum.

4. Final Considerations and Conclusion

The addition of mammary secretion pH to the monitoring of peripartum mares not only provides another means for clinicians to assess imminent labor, but may also help provide a more accurate picture of fetal maturation. It has been suggested that mammary electrolytes change with fetal maturation, and the same pattern seems to apply to mammary pH. Clinicians that are using mammary electrolytes to monitor the foaling process should be aware of these different patterns to better understand the behavior of their mares.

Fig. 8. Calcium elevation pre-foaling in mares for patterns 1 (red line, mare foaling with low pH and high calcium), and pattern 3 (blue line, when mare foals with alkaline pH and low calcium levels).

Fig. 9. Representative samples from mares presenting pattern 2. This pattern is characterized by a slow reduction in pH. Once the pH of pre-foaling secretions is acidic, mares will foal when pH is around 6.2.
provide a parameter for induction of parturition may find the combination of electrolytes and pH a more reliable indicator of fetal maturity.

Collection of daily mammary secretions, even for up to 3 weeks before foaling, does not seem to negatively affect colostrum quality. In our clinic, mares with prolonged decreases in mammary pH before foaling were mares at higher risk for dysmature or critically ill foals, and with more data, these prolonged decreases in pH may be an indication of when to expect intervention at foaling, or a high-risk foaling.

In summary, mammary-secretion pH is a useful test for imminent foaling, and can be measured with the use of a simple test strip or with a pH meter capable of measuring many samples without the need for replacement parts, given that is needed with commercial milk calcium test kits. Although the majority of mares will demonstrate a sharp decrease in pH in the 24 hours before foaling, there are some mares that experience a decrease in pH days before foaling, or such a sudden decrease that it may be missed with once a day pH sampling.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

References and Footnotes


Fig. 10. Represents three mares with pattern 3; mares with this pattern foal with an alkaline pH (>7.5).

Fig. 11. Lack of inversion in the concentrations for sodium/potassium before foaling in mares with pattern 3 (i.e., mares foaling with high pH, low calcium, and high chloride).
Effect of Two Levels of Hemospermia on Stallion Fertility

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A low level of blood (5% v/v) in an ejaculate does not impair fertility, whereas a high level (50% v/v) does. Authors’ address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77845; e-mail: ceturner@rocketmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Hemospermia can occur consistently or intermittently and has been described as a factor associated with infertility/subfertility in stallions. The aim of this study was to evaluate the effects of two levels (low and high) of blood contamination (5% and 50% v/v, respectively) of stallion semen on fertility.

2. Materials and Methods
Twenty-four reproductively sound mares and one fertile stallion were included in the study. Each mare was inseminated on three consecutive estrous cycles with one of three randomly assigned treatments consisting of 10 mL of previously centrifuged and extended semen containing $2.5 \times 10^8$ total sperm with 0% (T0; control), 5% (T5), or 50% (T50) (v/v) blood. Pregnancy was diagnosed by transrectal ultrasonography at 14 days post-ovulation.

3. Results
Pregnancy rates did not differ between Groups T0 (18/24; 75%) and T5 (18/24; 75%; $P>0.05$), but pregnancy rate in Group T50 (0/24; 0%) was reduced ($P>0.05$).

4. Discussion
The amount of blood in an ejaculate is difficult to estimate based on the gross color change. For example, pink-tinged ejaculates contain <1% (v/v) blood, but ejaculates containing both 5% and 50% blood (v/v) are both red in appearance. This makes it difficult to visually estimate the amount of blood contamination in an ejaculate, and thus whether it will adversely affect fertility. Although 5% blood contamination did not decrease fertility, the minimum level of blood contamination required to reduce fertility is not known.

Research Abstract—for more information, contact the corresponding author

NOTES
HOW TO TREAT THE SUB-FERTILE MARE

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
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When Rescues Fail: Legal Considerations for Veterinary Involvement

Julia H. Wilson, DVM, DACVIM

Veterinarians must consider ethical and legal implications for providing services when equine rescue organizations collapse. A decision to participate should include review of state regulations that define cruelty, neglect, and abuse, as well as the veterinarian's roles to report, support law enforcement, investigate, and triage medical treatment. Author's address: Minnesota Board of Veterinary Medicine, 2829 University Avenue, SE Suite 401, Minneapolis, MN 55414; e-mail: julia.wilson@state.mn.us. © 2016 AAEP.

1. Introduction

Equine veterinarians may become involved in failure of an equine rescue as the rescue's veterinarian, a community veterinarian, or when notified that a large group of horses need immediate assistance. Collapse of a large equine sanctuary, retirement farm, or failed horse farm may be very similar. Based on the veterinarian's oath, there is an ethical responsibility to provide professional expertise to improve the animals' welfare. There are also legal responsibilities to consider. The scope of a veterinarian's role will depend on the circumstances, the number of veterinarians that can be mobilized to triage and treat the animals, and realistically, assessment of the time commitment and lost revenue. Communities and clients expect veterinarians to lead efforts to address both the immediate needs of the animals and any other health abnormalities. With experience and training, veterinarians can meet that expectation and greatly affect the outcome for the horses. Very few clients are likely to protest if a veterinarian reports a rescue that has mistreated the animals, even if the rescue is that veterinarian's client.

2. Methods

Veterinarians may take on a role in resolution of failure of an equine rescue at several stages. First, the rescue may be the veterinarian's client, but educational efforts to improve the horses' welfare failed. The veterinarian may be familiar with the farm or suspect trouble on the basis of animals that are brought into the equine clinic. Similarly, a veterinary client or concerned volunteer may insist that the veterinarian intervene based on what that person has observed or heard. The first notice of trouble may be a call from a humane agent, animal control officer, or law enforcement who may ask the veterinarian to look at the animals and provide a professional opinion. After a decision has been made that the animals must be seized or surrendered, a veterinarian may become involved in triaging the multiple medical issues that are often present as well as documenting the condition of the animals. All entry points need the veterinarian to be a strong advocate for the horses' welfare. There are legal ramifications that must be reviewed given that findings at any
Abuse Reporting Requirements by State

In recent years, several states have focused their attention on animal abuse, neglect, and cruelty reporting by veterinarians, health care providers, and other social service providers. The clickable map below shows state laws and regulations that AVMA is aware of which require or encourage veterinarians and veterinary technicians to report animal abuse and cruelty. The map also includes states that provide civil or criminal immunity for good faith reporting of animal abuse. Keep in mind that veterinary professionals may report suspected abuse to authorities even in the absence of such a legal requirement.

Fig. 1. American Veterinary Medical Association’s Advocacy web site, a tool to quickly look up animal cruelty regulations in each state.

entry point stage may quickly evolve into a criminal investigation.

What is the definition of animal cruelty in the state? Failure to provide adequate feed, water, and shelter as well as basic health care are unfortunately common in cases of rescue failures. These failures may be defined as acts of omission that justify legal intervention. Many states include neglect under the definition of animal cruelty. Analysis of the situation may also suggest that the responsible person fits the definition of hoarding, which is often linked to mental illness.

When a veterinarian becomes aware that animal welfare has been compromised at an equine rescue or client’s farm, the first step is to review reporting requirements for the state. Veterinary technicians are affected by legal requirements in many states as well. The American Veterinary Medical Association provides an excellent resource that is frequently updated and easily accessible (Fig. 1).

This web site provides five key pieces of information for each state: 1) who must or should report suspected cruelty; 2) whether reporting is mandatory, voluntary, or not required; 3) what are reportable offenses; 4) civil immunity, if any, for good faith reporting; and 5) to whom suspected cruelty should be reported. The site also provides links to the specific state statutes or rules for additional detail. Among the details, the veterinarian should find and review the state’s definition of cruelty, and any law that pertains to a veterinarian’s role in investigation and documentation of cruelty. Increasingly, states are enacting legislation that recognizes that animal cruelty and neglect are linked to abuse and cruelty to people and mental health. Law enforcement should be aware of this link and anticipate the potential need for a two-pronged investigation. Legislative updates on bills under consideration or new laws about animal abuse are provided monthly by the National LINK Coalition via the free e-newsletter, The LINK-Letter (www.nationallinkcoalition.org).

In reporting suspected cruelty, regulations on the confidentiality of medical records should be considered based on the wording in the state’s veterinary practice act. Relinquishing records to law enforcement or humane agents may be allowed or require either owner permission or a subpoena from law enforcement. State practice acts can be retrieved quickly on the American Association of Veterinary State Board’s Web site (www.aavsb.org) by selecting the “Board and Agency Directory” option. After choosing the state or province, the site provides the link to the practice act and rules. Once the PDF is opened, a simple shortcut to find the pertinent lan-
guage is to use the key combination “Control + F”
function, then type in the phrase, “medical record.”
This then highlights all mention of these words in
the document. Alternatively, the board's staff may
be able to answer the questions. Confidentiality
constraints on medical records, investigative data,
or ongoing legal processes may also apply to media
interviews about the rescue collapse.

A phone call to law enforcement, humane agent,
or animal control officer to report neglect and/or
cruelty can be followed up with a signed affidavit to
law enforcement. This should be a statement of the
medical history and facts, signed by the veterinarian
and witnessed by a notary. The affidavit should
request action. If there is no action, the affidavit
can be taken up the chain of command.

When a veterinarian is asked to accompany law
enforcement, humane agents, or animal control offi-
cers to go onto a farm for a possible cruelty investi-
gation, legal preparation is required. In most
states, a search warrant is needed first. The veter-
inarian might otherwise be trespassing, and unable
to look at the animals. The link between animal
hoarding, mental illness, and at times human abuse
is another reason to make a joint visit with law
enforcement. In addition, observations made
can be taken up the chain of command.

When a veterinarian is asked to accompany law
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hoarding, mental illness, and at times human abuse
is another reason to make a joint visit with law
enforcement. In addition, observations made
without a search warrant may not be admissible in
criminal cases.

Criminal investigation of the rescue’s managers or
owners may be necessary and is best accomplished
with input from both law enforcement and a veter-
narian with forensic training. Accuracy and com-
pleteness of a veterinarian’s report is critical for
successful prosecution. Depending on the state’s
laws, neglect, abuse, or intentional cruelty to horses
may be a misdemeanor or felony offense. Maxi-
mum sentences for a person convicted of animal
abuse are also highly variable, and may depend on
factors such as demonstrable intent, permanent
harm, mortality, and previous animal cruelty
charges against the individual. Unfortunately,
some states have no animal cruelty laws whatsoever
or jurisdictions may choose to not enforce the laws.

Veterinarians that are recruited to triage and
treat surrendered or seized horses must be aware of
the definitions of cruelty, neglect, and abuse for that
state as well. Language chosen in medical reports
should reflect the language in those definitions.
The presence of infectious diseases such as strangles
may be reportable to the state veterinarian as well
as affect whether the animals should be sheltered in
place, not moved to a state or county fairgrounds, or
kept in isolation facilities at a veterinary clinic.

Licensing requirements must be heeded if the vet-
inarian will be working temporarily on the scene.
Some states may allow a veterinarian licensed in
another state to work as a consultant under the
supervision of a veterinarian licensed in that state.
Alternatively, the state practice act may make ex-
ceptions for emergency situations. These legal pro-
visions should be ascertained before beginning work

with the surrendered or seized animals. The
state’s law may also define who seized animals be-
long to. This may be important for obtaining con-
sent for treatment.

Requirements for medical records should be kept
in mind when evaluating the animals. State prac-
tice acts and rules may be quite detailed about what
should be included. In a forensic investigation,
even more detail and photographs are critical for
successful prosecution. Adequate support staff to
meet these needs should be planned in advance if
possible. Equine specific evaluation forms are
available from the American Society for the Preven-
tion of Cruelty to Animals veterinary investigation
team. Original records from triaged horses may
need to legally remain with the veterinarian, in
which case copies can be provided to law enforce-
ment for cruelty prosecution if necessary.

Authority to euthanize animals may be specified
in state regulations. Specific criteria may need to
be met for euthanasia and should be documented in
the record for the animal. If multiple horses need
to be euthanized, regulations pertaining to carcass
disposal must also be considered and may influence
the choice of method for euthanasia. If a forensic
necropsy is needed, taking the remains to a diagnos-
tic laboratory is ideal, but removal of “evidence” may
also be under legal constraints and require written
permission of law enforcement.

Responsibility for the cost of veterinary evalu-
ation and treatment of the horses may be found in
state regulations. Local or county government
funds, however, may not be sufficient for veterinary
expenses or upkeep of the seized animals. This is
important to understand and reinforce with local
officials. In counterpoint, this need to be paid for
professional expertise in an economically challenged
area may discourage a request for veterinary serv-
ces. The cost of housing seized horses may also
fall on the municipality and further discourage tak-
ing action such as removing the horses. Nonprofit
organizations may be able to contribute funds, vol-
unteers, feed, transportation, and facilities. Moti-
vated clients may be willing to use social media to
help raise funds as well.

A quick check with the veterinarian's liability in-
urance provider before beginning the work may be
prudent to determine coverage and ask whether a
liability waiver for non-employees is needed. The
likelihood of injury escalates if there are stallions
and other horses that cannot be handled.

Relocation of large numbers of horses into foster
care or other rescues may be challenging and re-
quire a coordinated effort between multiple re-
ponding organizations. Veterinarians should be
familiar with requirements for health certificates
for interstate travel if such will be required. Some
form of medical record sharing with new
caretakers should be pursued, even if it is not the
full forensic file.
The final legal piece for consideration is the veterinarian’s role in prosecution. The district attorney’s advice should be followed in both preparation of reports and court testimony. Cases of equine cruelty that were successfully prosecuted are available through animal welfare organizations. These can guide those who are not familiar with strategies for successful prosecution.

3. Discussion and Conclusions
A veterinarian can more effectively assist a large number of horses surrendered by or seized from a failed rescue by becoming familiar with the legal details for that state. A group of informed veterinarians in a state can more rapidly form a cohesive team. Preplanning for such an emergency at the level of a state veterinary association or animal health agency can include a manual with a summary of these parameters as well as protocols. An incident command system can be established or encompassed by the state’s disaster or emergency veterinary medical assistance team. However, legal role definitions must be incorporated in the organization of the team and decision making. This framework could also include a designated media spokesperson that is familiar with the legal constraints on confidential information.

Local equine veterinarians are critical to resolution of the failed rescue’s equine welfare crisis. These practitioners are most likely to know the law enforcement officers, sites for temporary housing, and potential volunteers to assist with the task, if volunteers are needed or allowed. This veterinarian’s input is critical even if the local practitioner cannot dedicate a large amount of time to the effort. This veterinarian is likely to be the first person to realize that the number of horses exceeds local capacity for veterinary care and housing. Calls to veterinarians and organizations with training in large-scale equine humane seizures should be made early in the process. Invaluable advice and additional resources may be available.

Positive working relationships with law enforcement and humane officers are very important and require nurturing. Law enforcement may have little knowledge of horse husbandry and fail to recognize underfeeding, signs of disease, and abnormal behavior. The veterinarian must then also take on the role of educating law enforcement on standards of care to persuade law enforcement leadership to take action.

Support from organizations and veterinarians with strong backgrounds in humane investigations should be sought as early as possible. Veterinary forensics is a rapidly evolving field with significant overlay with human crime investigation. Animal cruelty, abuse, and neglect are linked to human cruelty, abuse, and neglect. Mental health professionals can be a valuable addition to the intervention team.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnote

*https://www.avma.org/KB/Resources/Reference/AnimalWelfare/Pages/Abuse-Reporting-requirements-by-State.aspx
The Equine Veterinarian’s Role in Potential Cases of Animal Abuse

Rachel Touroo, DVM*; and Nicole Eller, DVM*

Equine veterinarians may come across cases of animal abuse during the course of daily practice, or may be asked by law enforcement to assist in the investigation and prosecution of a case. The veterinarian’s role in a potential case of animal abuse involves crime scene investigation, the examination of live and deceased animals, authoring a forensic veterinary statement, and the provision of expert witness testimony. Therefore, veterinarians must have a thorough understanding of their role and how to identify, collect, and preserve veterinary forensic evidence. Authors’ address: American Society for the Prevention of Cruelty to Animals, 520 8th Avenue, 7th Floor, New York, NY 10018; e-mails: rachel.touroo@aspca.org; nicole.eller@aspca.org. *Corresponding and presenting authors. Copyright © 2016. The American Society for the Prevention of Cruelty to Animal (ASPCA). All rights reserved.

1. Introduction
Veterinary forensic medicine is an emerging and rapidly developing branch of veterinary medicine. It is essential for veterinarians to be involved in cases of animal maltreatment, given that veterinarians are and should be the leaders for setting the highest standards for animal welfare in society. Not only does society demand the investigation of crimes against animals, but crimes against animals affect more than just animals. There is a strong and established link between human violence and animal cruelty. Crimes against animals can be a warning sign of future violent acts, and individuals who witness animal cruelty can become desensitized to violence. Animal abuse may also occur in conjunction with other crimes such as domestic violence and the illegal sales of drugs and guns. Having taken an oath, veterinarians have a duty not only to protect and serve animals but humans as well. Violence is a public health matter. By addressing animal abuse, veterinarians have the potential to save human and animal life as well as reduce suffering. Opportunities are increasingly available for veterinarians to educate themselves on these topics. Both a Graduate Certificate and Master’s Degree in Veterinary Forensic Sciences are now available online through the University of Florida. In addition, more veterinary schools are beginning to offer elective courses in the area of veterinary forensic medicine and publications on the topic have become more plentiful.

Veterinarians play a critical role in animal abuse cases, encompassing an array of duties within the context of veterinary forensic sciences. Veterinary forensic science is the application of a broad spectrum of sciences, including veterinary medicine, to answer questions of interest to a court of law. The term “forensic medicine” is used to encompass all aspects of forensic work of a medical nature. In the past, this term was often used interchangeably with
“forensic pathology.” Forensic pathology, however, refers to the branch of forensic medicine that deals with death investigations. More recently, the term “clinical forensic medicine” is applied to the branch of forensic medicine involving the living.

There is a spectrum of the levels of animal maltreatment, most laws use the term, “cruelty,” but maltreatment may also be described as “abuse” or “neglect.” Legal definitions of these terms vary from jurisdiction to jurisdiction but in general the term, “abuse” refers to the willful failure to provide care and harmful behaviors that result in maltreatment regardless of the intent, motivation, or mental condition of the perpetrator.1 Whereas “cruelty” implies more deliberate infliction of pain from which the abuser derives enjoyment or amusement2, “neglect” tends to be the most commonly encountered form of maltreatment and refers to the failure to provide care or an act of omission, as opposed to cruelty, which would be an act of commission.

2. The Evolution of a Case
Veterinarians may be approached by law enforcement or a humane agent to assist with a case investigation or may come across a suspected or known case of abuse during the regular course of their day. This may take the form of a rescue that has exceeded its capacity to care. For example, in April 2009, a large-scale rescue of 211 horses was accomplished by cooperation between several groups, both national and local. The rescue started off with the goal of being a sanctuary for Bureau of Land Management (BLM) mustangs that had gone through three adoption events without finding a home. These animals, deemed “unadoptable,” faced life in a holding pen, or possibly illegally being sent to slaughter. This sanctuary meant to give these horses, and others whose owners could no longer care for them, an alternative place to go. However, things began to go wrong as the horse population climbed and funds and hay became limited.

A mid-April investigation spawned by Internet chatter, concerned and observant neighbors, diligent veterinarians, county law officials, and others uncovered the grisly truth that at least 74 head of dependent horses and burros were allowed to starve to death during the winter. Following this discovery, 211 head of horses, mules, and donkeys in varied but serious stages of neglect were rescued from the premises. Law enforcement flew over the rescue, spotting two pits filled with horse carcasses and other scattered remains. BLM officials were alerted and went to the ranch, confiscating one emaciated BLM horse and learning that another three were dead. A charge of felony animal cruelty was filed, resulting in the jailing of the owner.

Fortunately, the organizations involved had already developed extensive databases of trained volunteers who could be called upon to respond when needed, along with a list of each volunteer’s credentials, training, and expertise. This is one of the keys to dealing with large-scale animal disasters, whether natural or man made. Veterinarians must get involved by reaching out to local and state government disaster-relief agencies and state veterinary medical associations, as well as nonprofits and large-animal technical rescue groups that are developing in many states. This case relied on over 700 volunteers as well as a team of dedicated veterinarians and veterinary students.

3. Recognizing Abuse
Veterinarians are not traditionally trained to identify features that raise the index of suspicion of animal abuse or signs consistent with or highly suggestive of abuse. In addition, veterinarians often fall into the trap of thinking that owners who care enough about their animals to provide veterinary care are unlikely to abuse their animals. This is simply not the case. The largest barrier to diagnosing abuse is the existence of emotional blocks in the minds of veterinary professionals. These can be so powerful that they prevent the diagnosis from even being considered in obvious cases. The most important step in diagnosing animal abuse is to force oneself to consider this as a differential diagnosis.

For many equine veterinarians, abuse will likely be observed or suspected on the farm as opposed to in a clinic setting with other people around. How the situation is approached depends on the relationship with the client. But do not forget to treat the animal first. Although a crime may have been (or is being) committed, do not compromise timely treatment of the animal. A conversation with the client may shed some light, such as indications that the abuser may be a spouse or significant other. Taking thorough notes, and possibly photographs, if this can be done without arousing suspicion from the client, is helpful; however, be aware of getting yourself into a situation that may become volatile or unsafe. If the circumstances do not allow for documentation at the farm, do a thorough examination with detailed medical records as normal, address the presenting complaint, and make additional notes when you leave the farm.

It is important to note that animal abuse is a legal, not medical, determination. Just because a veterinarian may believe that an act qualifies as abuse does not mean that the law recognizes it as such. Therefore, the veterinarian must be familiar with the applicable laws in order to make an informed opinion as to whether an act or omission may qualify as abuse, but ultimately this is the determination of the prosecuting attorney. When reporting potential or suspected animal abuse it is not the duty of the veterinarian to identify suspects or determine guilt or innocence. All known or suspected cases should be reported, allowing for law enforcement to investigate and for the prosecuting attorney...
animal abuse. To alleviate this issue veterinarians are expected to report known or suspected
their position within the Incident Command System
The veterinarian(s) involved should be aware of
following:
[60x202]cident management approach that allows for the
[60x224]System, is a standardized, on-scene, all-hazards in-
[60x235]chaotic. The Incident Command System, estab-
[60x257]Without a structured system, this can become very
[60x268]can involve many agencies on many different levels.
Animal cruelty cases, particularly on a large scale,
4. Assisting in a Large-Scale Investigation
Animal cruelty cases, particularly on a large scale,
can involve many agencies on many different levels.
Without a structured system, this can become very
chaotic. The Incident Command System, estab-
lished under the National Incident Management
System, is a standardized, on-scene, all-hazards in-
cident management approach that allows for the
following:
1. The integration of facilities, equipment, per-
sonnel, procedures, and communications oper-
ating within a common organizational
structure
2. A coordinated response among various juris-
dictions and functional agencies, both public
and private
3. Common processes for planning and manag-
ing resources
The veterinarian(s) involved should be aware of
their position within the Incident Command System
and communicate effectively with law enforcement
and any direct reports assigned to assist them.
On a local level, veterinarians asked to be in-
volved in a large-scale cruelty case will likely have
colleagues with whom they already have a rela-
tionship, and a medical team can be developed.
It is helpful to have made such contacts and de-
velop a plan prior to an incident, so that this team
can be pulled together quickly and efficiently.
Such a team might include individual veterinari-
ans, veterinary clinics, vet schools and students,
local rescue organizations, local emergency re-
sponse personnel, and other individuals and
groups. This communication is also important
for a plan moving forward after the animals are
seized, given that they will need ongoing care,
housing, and documentation of conditions and im-
provement. It is also important to communicate
clearly with incident command as to who will be
covering payment for services rendered, covering
the costs of diagnostic testing as recommended for
health and evidentiary purposes, and the costs of
animal care and housing post seizure and through
adjudication.
When large-scale cases arise that exceed a locality’s
abilities or resources, there are a variety of national
organizations, such as the American Society for the
Prevention of Cruelty to Animals (ASPCA), which
can provide direct (boots-on-the-ground) assis-
tance to law enforcement at the local, state, and
federal level and can be tailored to fit the needs at
hand. The ASPCA and others also provide grant
funding to law enforcement across the country to sup-
port their work in animal-abuse cases. For more infor-
mation on assistance available at the ASPCA, please
visit www.aspcaapro.org.
The initial number of veterinarians needed on a
case will depend on the number of animals, number
of scenes involved, and somewhat on the experience
of the veterinarians and the suspected condition of
the animals. On scene, the forensic veterinarian is
responsible for the identification and documentation
of animal evidence as well as non-animal medical
evidence. An on scene, treatment veterinarian
may also be necessary to focus on patient care, such
as handling critical animals, which may be sent to a
predetermined facility off site after being stabilized.
A federally accredited veterinarian should be on
scene to perform Coggins testing and issue health
certificates as needed.
Moving forward into veterinary forensic examina-
tions, a good rule of thumb is to have a veterinary
forensic team for every 50 equids to complete exa-
ninations within a few days depending on the extent
of the medical conditions present. Ideally, these
teams would include a veterinarian, handler, tech-
nician, and a scribe. The person responsible for
photographs (typically the veterinarian) should be
familiar with the equipment to obtain clear, useful
images, which are an accurate depiction of the
evidence.
5. Identification, Collection, and Preservation of Evidence

To assist law enforcement with an investigation of potential animal abuse, the veterinarian must understand the basics of evidence identification, collection, and preservation. Evidence is generally defined as anything that can demonstrate or disprove a fact in contention. Such facts may be anticipated based on the applicable laws as well as prior experiences. More specifically, evidence is used to demonstrate guilt or innocence, to identify victims, and to identify suspects. Care must be taken to ensure the integrity of each item of evidence, given that everything must be done with the ultimate goal in mind to withstand scrutiny in the courtroom. The veterinarian must recognize that their duty is to the court, assisting the trier of fact (the judge or the jury) in understanding the evidence at hand and in effect, act as an advocate for the truth.

To determine what may be important evidence in a given case, the crime scene and the forensic examination should be approached within the context of potential criminal prosecution. Questions must be considered and answers sought within this context. Again, such questions will be based on the applicable laws, prior experiences, as well as specific questions that law enforcement may be trying to address.

Veterinarians must be familiar with the processing of an animal crime scene, specifically as it relates to their role on scene. Initially the scene will be secured by law enforcement before anyone will be allowed on scene. Once the scene is secured, documentation should begin and typically will occur in phases as follows.

Phase 1: Document the Condition in Which the Scene was Found Upon Arrival

This should include overall photos and possibly video of the areas covered under the search warrant. This phase is typically completed by law enforcement.

Phase 2: Documentation of Each Animal and Their Environment

This phase can be further broken down into stages.

Stage 1: Critical Triage

Critical triage is conducted during the veterinarian’s initial walkthrough of the property. Triage on scene is a rapid, visual sorting of animals for examination and treatment priority based on their medical condition. Critical triage is done to identify animals in immediate need of medical care and is the responsibility of the veterinarian.

Critical triage requires an expedited intake procedure to provide necessary and timely medical treatment. Intake requires assignment of a unique animal identification number and documentation of the animal in situ. Documentation should include photographs as well as written notes. It is important to remember that each animal is an individual item of evidence. In the case of a critical animal requiring immediate treatment, this evidence will be altered the moment treatment begins. Document the animal as thoroughly as possible prior to beginning treatment, but obviously not at the expense of causing the animal further distress (Fig. 1).

Step 2: Intake Triage

Following critical triage, noncritical animals should be more closely assessed and their environment documented. Intake triage should be conducted by the veterinarian during the second walkthrough of the property. It is imperative that the living conditions of each animal not be altered in any way until they have been observed by a veterinarian, documented, and photographed.

During intake triage, animals requiring a more in-depth assessment or treatment on scene prior to transport should be flagged. A simple color-coding system to use is red for critical animals, yellow for animals that require further assessment and documentation or treatment prior to transport, and green for animals that are ready for transport. Blue may be used for animals that are exhibiting signs of infectious disease. These animals, unless critical, will then be handled last and transported separately, if possible. Ideally, there is an isolation area set up in the barn or shelter that will be housing the animals off site. Again, be sure to document as thoroughly as possible prior to initiating any treatment on any animal, given that any evidence will be altered from this point forward.

It is imperative to document each individual animal’s living conditions, given that they may hold information that will either contradict or corroborate the animal’s physical examination findings (Figs. 2 and 5). Therefore, it is important to be able to accurately illustrate the living conditions from which each individual animal came and demonstrate how that environment may have directly affected the animal. This is especially true in cases of neglect. Given this importance, the veterinarian must take an active role in this documentation, including scene notes and photographs. If the veterinarian is not the photographer, the veterinarian should be actively directing the photographer to get the necessary images. The veterinarian is the person who will also identify other details, such as quids of hay on the ground, or toxic plants eaten down along the fence line in a dry lot. In addition, the location of each animal will need to be documented by either a sketch or other mapping technique. This is ideally completed by a crime scene analyst or technician.

Stage 3: Deceased Animals

Deceased animals are considered noncritical and are often given a non-animal physical evidence item
number rather than an animal identification number when seized in conjunction with live animals. Such a numbering system helps to eliminate confusion. If deceased horses are to be necropsied, the loading, transport, and location of necropsy should be predetermined to avoid delay (Fig. 3).

**Stage 4: Post-Removal Photos**

Following the removal of each animal, more thorough documentation of the living space can be completed. Mid-range and close-up photos of the living space should be completed once the animal has been removed. Such photos should include, but are not limited to, any receptacles, presence or lack of food and water, quality of food and water, shelter and fence construction and possible hazards, feces, and urine (Fig. 4). It may also be necessary to record the dimensions of the living enclosure in comparison with the measurements of the animal housed within the space. Such measurements can be recorded on the sketch showing the location of each animal. In a group or pasture situation, be sure to note the numbers and sizes of horses expected to use one shelter.

**Phase 3: Non-Animal Evidence**

In addition to recognizing and documenting animal evidence, the forensic veterinarian may assist law enforcement with the identification of non-animal medical and also non-medical evidence. This could include items such as medications, supplements and surgical supplies, or identification of implements having certain purposes (Fig. 6). Some items of evidence may be overlooked by law enforcement officers who are not familiar with the particular crime type. Similarly, a forensic veterinarian can assist law enforcement with the potential evidentiary value of an item, given that they may not be aware of an item’s full evidentiary value.

**Phase 4: Document the Condition of the Scene Upon Exit**

This should include overall photos and possibly video of the areas covered under the search warrant. This phase is typically completed by law enforcement.

Evidence will also be identified, collected, and preserved during the forensic examination. Veterinarians must be familiar with the necessary components of a forensic examination of both live and deceased victims. A forensic medical examination is a detailed and thorough examination performed to methodically document examination findings and facilitate the collection of evidence from the patient’s body. Like any other physical examination or necropsy, this examination should be performed in a systematic manner, noting all normal and abnormal findings and evaluating all body systems. There should also be a standard protocol for each animal. This protocol may vary from case to case depending on the type and scale but the same protocol should be used for each animal in a given case.

Forensic examinations should occur as soon as rational. They may occur on scene but tend to occur more commonly off scene given the uncontrolled environment and lack of access to necessary equipment on scene. However, cursory or brief exams as mentioned previously may be conducted on scene to provide necessary treatments prior to transport as well as document transient evidence, such as mild dehydration.

Photographs are a fundamental component of a forensic examination. In addition to written notes, photographs should be obtained for several different purposes.

1. Identify the victim
2. Demonstrate the condition of the evidence at the time of discovery
3. Record and document evidence that cannot be preserved or left unaltered
4. Allow for later review of the evidence
5. Document injuries or conditions and record what they looked like before and after medical intervention
6. Illustrate and supplement a written report
7. Demonstrate the absence or presence of alleged findings
8. Present in a court of law, the items of evidence as they were found, thereby validating the testimony being presented

Forensic examination photos should be taken in a series with the first photo depicting a photo board clearly stating the case number, date, location, or address where the photos are being taken, the animal identification number and the photographer’s name. The second photo of the series should be of the animal with the photo board (Fig. 7). Subsequent photos do not need to contain the photo board but may contain a smaller label as needed. Overall photos should be the third step in the series, treating the animal like a cube, obtain a photo of all six sides of the animal, as allowable given the species. Overall photos should be followed by orientation photos (Figs. 8 and 9). Any findings should be photographed in greater detail, starting with an orientation photo so the viewer understands where on the body the finding is located. The orientation photo is followed by a close-up photo with and without a forensic ruler. The scale or ruler serves various purposes but most importantly it demonstrates that the photo is a clear and accurate representation of the finding observed. This is performed by clearly identifying color, if any distortion is present and that the photo is in focus. The forensic ruler also provides measurement. It is important to note that photos should never be erased, if taken by mistake or of poor quality, they should still be retained. Deleting images can create a gap in the metadata which could be called into question.
In addition to being competent in the identification of evidence on scene and on the body, the veterinarian also needs to be competent in the collection and preservation of evidence. Evidence is commonly lost as it may go undetected or disregarded or fail to be properly collected or preserved. In order for evidence to be authenticated in court, it must be accounted for at all times. This is done to demonstrate that the item was not tampered with and is in fact the item that was removed from the crime scene or animal. In addition to witness testimony, a chain of custody and evidence packaging are used to demonstrate authentication. A chain of custody is the chronological documentation of every person who has had contact with the item from the time it was seized until it is disposed of. This includes how the item was packaged, the persons involved, dates, times, and purposes of all transfers. All items of evidence should be accompanied by their original evidence receipt or chain of custody. An example of a chain of evidence form is available at: http://aspcapro.org/resource/disaster-cruelty-animal-cruelty-animal-fighting/sample-documents-cruelty-cases.

Items of evidence must be properly packaged to prevent loss or degradation. Reference manuals such as Crime Scene Investigation: A Guide for Law Enforcement, published by the National Forensic Science Center should be consulted to ensure proper packaging. Evidence must also be properly identified, labeled, and secured. The container label should include the following:

1. The case number
2. The item number
3. The investigating agency
4. Location of collection
5. Description of the item
6. Name of the individual who collected the item
7. The date and time the item was collected

To properly secure evidence, it should be properly sealed and stored. To seal an item of evidence, the package should be secured with frangible evidence tape, which bears the packager’s initials and the date the item was packaged. Care should be taken so that these items cross over the evidence tape onto the package. Evidence should be stored in a secure location with access restricted and monitored. Protocols should be in place for evidence storage and items should be signed in and out of storage. Evidence should not be disposed of until written consent has been obtained from the submitting agency. Disposal should be documented on the original evidence receipt, which should be retained.

6. Forensic Veterinary Statement
The veterinarian will determine an opinion based on the facts of a case. These facts will come from the history, medical examination findings, crime scene findings, diagnostic and forensic test results, as well as potentially other sources. These facts will need to be proven in a final report, which may be referred to as the forensic veterinary statement. The responsibility to “prove” or “disprove” a case does not lie on the veterinarian. The case investigation is a multidisciplinary approach and veterinary evidence is only part of the case. Ultimately, it is the prosecutor’s duty to prove the case and the judge or juror’s duty to decide guilt or innocence. The veterinarian should simply present the facts and their interpretation or conclusions drawn from these facts.

The purpose of the forensic veterinary statement is to clearly convey the facts of the case, which fall into the veterinarian’s area of expertise, to assist the judge and/or jury in understanding the evidence at hand. The forensic veterinary statement must educate the investigators, prosecutor or defense attorney, the judge, and the jury. Therefore, this statement is not necessarily directed toward other veterinarians and must be easily understood by the lay audience it is intended for. The veterinarian must ensure that the court understands the evidence while also acting as an advocate for the truth. However, the veterinarian must be aware of their limitations remaining within their area of expertise, understand the gaps in veterinary forensic science, and not extend beyond what the current science allows for us to state. The veterinarian must be impartial and only draw conclusions based on what the evidence shows.

Unfortunately, there is no standard format for the veterinary forensic statement; however, it is more than just your physical examination findings. The authors recommend that the following components be included in the veterinary forensic statement involving live animals.

1. Introduction
   a. Investigating agency, lead officer, this agency’s case number and animal identification number
   b. Reason for the examination
The authors recommend that a forensic necropsy report included the following components.

1. Introduction
   a. Investigating agency, lead officer, this agency’s case number and animal identification number
   b. Purpose of the necropsy
   c. Date, time, and location of the necropsy
   d. Those in attendance
   e. Signalment and other identifying information regarding the animal

2. Crime Scene Findings
   a. Summary of findings, opinions and discussion
   b. Note duration of conditions, the long-term and short-term effects, conditions that should have been apparent to the owner/caregiver and conditions that are preventable/care that should have been provided

3. History
   a. A medical history for the animal may or may not be available

4. Medical findings
   a. Pertinent physical examination findings with reference to complete examination findings
   b. Pain assessment as applicable
   c. Diagnostic tests and results, listing and explaining all results
   d. Treatments provided and response

5. Conclusions
   a. Summary of findings, opinions and discussion
   b. Note duration of conditions, the long-term and short-term effects, conditions that should have been apparent to the owner/caregiver and conditions that are preventable/care that should have been provided
EMERGING INDUSTRY ISSUES — WHEN A RESCUE GOES BAD

Fig. 6. Photo depicting boxes of medications and veterinary supplies found on a scene.

Fig. 7. Second photo of the series, including the animal with the photo board. Note that the animal is also marked with identification number from prior transport.

Fig. 8. Close-up photo of a lesion using the ABFO No. 2 scale. This should be the third photo of a lesion, an orientation photo and a photo without the scale.

Fig. 9. Good intra-oral images of dental conditions can be very compelling evidence of neglect.

a. Personal observations or information provided
3. History
   a. A medical history for the animal may or may not be available
4. Gross description of findings
   a. Presentation of the body
   b. Postmortem changes
   c. External examination findings
   d. Internal examination findings

5. Gross diagnosis
6. Ancillary procedures, laboratory tests and results
   a. List and explain
7. Cause of death
   a. May also include manner of death, any contributory causes of death, mechanism of death, and estimated postmortem interval as applicable
8. Comments/Conclusions
   a. Interpretation and explanation of findings
      i. May be able to address duration and degree of pain and suffering as applicable
      ii. May want to note if the death is an approved method of humane euthanasia (AVMA guidelines on euthanasia)
Keep your audience in mind when writing your report. Your target audience is the lay individual, such as law enforcement, lawyers, a judge or the jury rather than another veterinarian. You should use appropriate medical terminology but explain what it means so that the lay reader can easily understand your report. In addition, it may be beneficial to summarize findings in conjunction with photographs to enhance understanding and further illustrate the magnitude of the condition. If there are numerous animals involved in a case consider using a table or chart to summarize the findings as well. Such tables or charts may be useful for the judge and/or jury and may serve as a reference during trial. Remember that all e-mails, photos, notes, and any other documents related to a case are discoverable and should be maintained and provided as requested. With this in mind, you should always approach all aspects of the case in an unbiased and professional manner. All original documents and photographs should be maintained. Feel free to make clean copies of your notes but always retain the originals. Photographs should be maintained in a system in which they cannot be altered and protocols should be in place for the handling of photographic evidence, given that you may be questioned about the integrity of your photos in court. Copies of photographs may be altered; however, you must maintain the original unaltered copy and document all changes made.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors are employed by the ASPCA.

References
What the Prosecutor Needs From Veterinarians to Support Legal Consequences

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In animal cruelty prosecutions involving equines, the equine veterinarian is the prosecutor’s most important resource and witness. An understanding of what the prosecutor needs from the veterinarian will make the equine veterinarian an effective and indispensable resource in animal cruelty prosecutions. Author’s address: Pine County Courthouse, 635 Northridge Drive NW, Suite 310, Pine City, MN 55063; e-mail: reese.frederickson@co.pine.mn.us. © 2016 AAEP.

1. Introduction
In prosecutions against individuals who have committed criminal animal cruelty against equines, the most important witness is the equine veterinarian. Equine veterinarians are essential in charging and proving a case. This paper will describe what the prosecutor needs from the veterinarian. Specifically, this article will provide an overview of what the prosecutor has to prove, the importance of submitting a good veterinarian report, the basics of expert witness testimony, and how to be an effective witness. This paper references Minnesota law; however, the laws are similar in most jurisdictions and based upon the same constitutional requirements; the concepts presented are applicable in nearly every courtroom.

2. An Overview of What a Prosecutor Has to Prove
After a case of animal cruelty is investigated, the investigative materials are sent to a prosecutor for review for criminal charges. The investigative materials typically consist of law enforcement reports, veterinarian or veterinary pathologist reports, humane agent reports, photographs, audio of interviews, and video of the scene. Once the prosecutor believes that there is a sufficient amount of materials, he/she must determine whether there is probable cause to charge a crime. “Probable cause” requires that there are sufficient facts such that under the circumstances, a person of ordinary care and prudence would entertain an honest and strong suspicion that a crime has been committed.

A prosecutor must also determine what crime to charge, as well as the corresponding penalty. In Minnesota, there are three chapters with numerous sections that detail various crimes and penalties involving the treatment of animals. For instance, the general crime of animal cruelty in Minnesota “is every act, omission, or neglect which causes or permits unnecessary or unjustifiable pain, suffering, or death.” The prosecutor must prove that the abuser knew or should have known that his/her actions caused the cruelty. In other words, a person cannot be found guilty of animal cruelty if it was due to an unforeseeable or unpreventable accident.

In addition to the crime, many states have different levels of penalties depending on the type of harm. For instance, if the animal cruelty caused great bodily harm or death in Minnesota, the crime...
is a felony. Great bodily harm means bodily injury which creates a high probability of death, or which causes serious permanent disfigurement, or which causes a permanent or protracted loss or impairment of the function of any bodily member or organ, or other serious bodily harm to a service animal or a pet or companion animal. A felony may result in a prison sentence. If the act caused substantial bodily harm, the crime is a gross misdemeanor. Substantial bodily harm means bodily injury which involves a temporary but substantial disfigurement, or which causes a temporary but substantial loss or impairment of the function of any bodily member or organ, or which causes a fracture of any bodily member to a service animal or a pet or companion animal. Harm less than great or substantial is a misdemeanor. Testimony from an equine veterinarian is necessary in determining the difference between a gross misdemeanor or felony based on level of harm, and a cause of death.

After a case is charged, the prosecutor has to prove the case beyond a reasonable doubt, which is the highest legal burden of proof. Minnesota law defines this burden as: “Proof beyond a reasonable doubt is such proof as ordinarily prudent men and women would act upon in their most important affairs. A reasonable doubt is a doubt based upon reason and common sense. It does not mean a fanciful or capricious doubt, nor does it mean beyond all possibility of doubt.”

Essentially, all the evidence presented by the prosecutor has to be consistent with the guilt of the defendant, and inconsistent with any other possibility. If the state and the defendant do not settle the case with a plea agreement (i.e., an admission of guilt from the defendant), the case is presented to either a jury or a judge. Proving a case requires testimony from witnesses and evidence.

An equine veterinarian is essential at every step of the prosecutor’s case to help prove animal cruelty.

3. The Importance of a Good Report

An important aspect of the prosecutor’s charging decision is the medical report received from an equine veterinarian. The report aids a prosecutor in determining whether the acts were intentional or due to a disease, the level of penalty based on the type of harm (e.g., whether it’s great, substantial, or something less), and the strength of the case based on the findings in the report. The completeness of the report also helps the prosecutor determine the strength of the equine veterinarian as a witness. For instance, a complete and thorough report indicates that the veterinarian will be a methodical and knowledgeable witness. It is also beneficial if the equine veterinarian familiarizes himself/herself with the local animal cruelty laws and levels of harm so that a report may be written to address the level of harm.

If the equine veterinarian’s findings, opinions, conclusions, results, or other materials are used as evidence in a criminal trial, he/she must testify. Simply submitting a report into evidence without testimony violates the defendant’s right to confrontation and has been repeatedly held impermissible by the United States Supreme Court and state courts. In other words, if an equine veterinarian provides any sort of expertise during an animal cruelty investigation, he/she can expect to be called to the witness stand if a case proceeds to trial. The rare exception is if an equine veterinarian is hired as a consulting expert during case preparation simply to help the state prepare its case, and is providing no testimony or evidence.

If an equine veterinarian prepares a report as part of the investigation or testifies for the state in a trial, the state must provide the defense “a written summary of the subject matter of the expert’s testimony, along with any findings, opinions, or conclusions the expert will give, the basis for them, and the expert’s qualifications.” The state must also provide the defense with reports of examinations, experiments, and scientific tests. Likewise, if the defense hires an expert, they must disclose the same materials to the state. The disclosure requirements give each side time to study the opposing expert’s materials, prepare for cross examination, and find weaknesses in the expert’s results.

The disclosure requirement also highlights the necessity for a good report. Whether a case goes to trial is based on a calculation of risk, especially by the defense. For instance, a defense attorney or his/her consulting expert will review an equine veterinarian’s report from the state prior to determining whether to go to trial. If they find that the report is thorough, reasonable, and objective, they may conclude that trial is too risky and convince their client to plead guilty based upon the strength of that report and the state’s expert. If they find that the report is biased, unprofessional, lacking in detail, or failing to dispose of alternative theories, they may find trial an acceptable risk given the numerous holes that can be exploited in that report. In other words, spending the time to write a clear, professional, objective, and thorough report will lessen the chance that an equine veterinarian will have to spend a considerable amount of time testifying and preparing for court.

4. The Equine Veterinarian as an Expert Witness

If a case clears all the legal hurdles and is not settled with a plea agreement, the matter is tried before a jury or a judge (both are called the “trier of fact”). The prosecutor has the burden to present evidence and witnesses to the trier of fact, and prove the case beyond a reasonable doubt. In an equine cruelty case, a prosecutor will typically call law enforcement officers, humane agents, representatives of rescue organizations, and lay witnesses. The most important witness a prosecutor will call is the equine veterinarian. A veterinarian is a strong witness because he/she can be qualified as an expert wit-
ness—a status that gives the veterinarian more power and leeway than what is afforded to a lay witness.

5. Legal Basics of Expert Testimony
Rule 702 of the Minnesota Rules of Evidence is the gateway rule that permits expert testimony in certain circumstances (the rule is similar to rules used in other jurisdictions). The rule states:

“If scientific, technical, or other specialized knowledge will assist the trier of fact to understand the evidence or to determine a fact in issue, a witness qualified as an expert by knowledge, skill, experience, training, or education, may testify thereto in the form of an opinion or otherwise. The opinion must have foundational reliability. In addition, if the opinion or evidence involves novel scientific theory, the proponent must establish that the underlying scientific evidence is generally accepted in the relevant scientific community.”

The rule is broadly phrased to include any area of specialized knowledge, whether it was gained through formal training, skill, or experience. The rule also contemplates expert testimony in the form of lecture or explanation. The expert may educate the jury so the jurors can draw their own inference or conclusion from the evidence presented.

When compared with lay witnesses, expert witnesses have more flexibility in the courtroom. Lay witnesses are typically prohibited from offering opinions, or may only offer opinions in limited circumstances. Expert witnesses may offer an opinion on the ultimate issue to be decided by the trier of fact. Lay witnesses are typically prohibited from “lecturing” or offering broad explanations. Expert witnesses also bring authority. Therefore, given the additional powers of an expert witness, a threshold must be met before they are allowed to testify.

6. Threshold for Expert Testimony
Before an equine veterinarian’s expert testimony is allowed in a trial, the judge must make three preliminary determinations:

1. Is the subject matter of the testimony outside the realm of common knowledge so that expert testimony can assist the trier of fact in reaching its decisions?
2. Does the expert, by way of education or experience, possess sufficient expertise or specialized knowledge so that opinions on this subject matter can assist the trier of fact?
3. Is the foundation for the opinion sound so that the opinion can assist the trier of fact?

Assisting the Trier of Fact
Judges will allow an equine veterinarian’s testimony when it assists the trier of fact. According to the Minnesota Supreme Court, “A reasonable test to be applied is whether the members of the jury, having the knowledge and general experience common to every member of the community would be aided in the consideration of the issues by the offered testimony.” The court also noted that, “We think... that such evidence should be received only where the subject matter is complicated or its operation difficult and embracing matters either in construction or operation not of common knowledge.”

In other words, if the testimony relates to matters of common knowledge, it will be of no use to a jury.

Expert testimony from an equine veterinarian will typically meet this threshold, especially in animal cruelty cases. Equine veterinarians have the medical training to describe to a jury how an act, omission, or neglect affected a particular animal, or produced unjustifiable pain, suffering, or death. Such matters are outside the scope of common knowledge, especially considering that animals cannot verbally describe the act, omission, or neglect, nor its effect.

Expert testimony in animal cruelty cases is also helpful with other aspects of proving the crime. For instance, the state has to prove that the act of cruelty was intentional. An equine veterinarian may distinguish between intentional acts and accidental acts. An expert may also link injuries to a weapon or suspect, or offer an opinion on how acts could have reasonably been prevented.

Qualifications of an Expert
Before an attorney can obtain expert opinions from an equine veterinarian, he/she must elicit evidence or statements from the expert to distinguish the expert from a lay witness. Although education, training, and knowledge are factors, courts have often viewed practical experience as the most important qualification. The determination is whether the witness’ “knowledge of the matter in relation to which his opinion is sought is such that it will probably aid the trier of the question to determine the truth.”

Sometimes, the lawyers are able to stipulate that a witness is qualified as an expert. In most cases, however, the proponent of the expert has to lay a foundation with testimony from the witness. In general, an equine veterinarian called as an expert witness should be able to discuss his/her education, licensure requirements, occupation, past employment, duties and responsibilities, internships, number of similar cases, membership and leadership in professional organizations, professional lectures and presentations, professional publications, and awards and recognitions. A good practice point is for a witness to explain the minimum qualifications in his/her field, and then explain how he/she exceeds those qualifications.

Foundation for the Expert Opinion
The facts or data establishing an expert opinion must be sufficient for an adequate foundation.

This determination is subject to a two part test:
“1. are these facts and data of a type relied upon by experts in this field when forming inferences or opinions on the subject; 2. is this reliance reasonable?” These requirements provide “a check on the trustworthiness of the opinion and its foundation.”

Basically, the judge has to be satisfied that the facts or data the expert is using as the basis of his/her opinion is trustworthy and helps guarantee the validity of the opinion. An expert may rely on facts or data that is inadmissible in evidence, such as hearsay, “including conversations with other expert witnesses, professional literature, personal observations, or lectures.”

With regard to reliability of the opinion with medical experts, Minnesota courts are flexible and defer to the expertise of the expert. The Minnesota Supreme Court has noted that “It is not necessary that medical opinion be capable of demonstration or that an expert speak with confidence excluding all doubt; it is enough that he state his opinion as true in his judgment.”

When the proponent establishes the basis for an equine veterinarian as an expert, that expert should be able to explain the facts and data underlying the opinion, and describe how it is customary to rely upon those facts and data in the field. For example, an equine veterinarian should be able to explain how he/she would typically examine an equine, how the examination relies on the findings of other individuals such as laboratory technicians, and the reasonableness of relying on personal observations, education, experience and scientific literature.
they may expect complicated and confusing testimony, or a boring lecture. They may also have questions about whether the expert is truly an expert; a belief that the expert is biased; or a notion that the expert is a condescending intellectual. An expert can counter these expectations by using clear, non-technical language; using visual aids; giving a thorough explanation of experience and education (e.g., an expert should discuss what sets him/her apart from others in the field); demonstrating fairness and objectivity; and showing that he/she is a normal person who is there to help the jury with a decision.

8. General Tips on Being an Effective and Prepared Expert Witness

There are a number of ways an equine veterinarian can be a prepared and an effective expert witness. First, the expert should always meet with the lawyer who chose him/her as the expert before giving any testimony. Of the tips discussed, this is the most important. This gives the expert a chance to explain to the lawyer his/her testimony, practice direct examination, discuss the order of what will be covered, and what exhibits will be introduced. Expert testimony is typically organized as follows: 1) introduction, 2) education and experience, 3) opinions, and 4) basis for the opinions. Meeting with the lawyer ahead of time will also give the expert a chance to put together testimony in a meaningful way, and prepare for cross examination by the opposing party. A meeting prior to court also helps the lawyer and the expert to come to a “meeting of the minds” with the proposed testimony and the manner in which the testimony will be used.

Second, an equine veterinarian should visit the courtroom when it is empty to familiarize himself/herself with the layout of the witness stand, the location of the jury box, and the location of the attorneys. An expert who knows the layout of the room beforehand can enter the courtroom with confidence.

Third, an equine veterinarian should listen to the questions, but speak to the jury. An equine veterinarian should think about the testimony as a conversation with the jury. The expert should look at the jury when answering, and be polite and friendly with responses to questions.

Fourth, prior to trial, an equine veterinarian should provide the attorney with everything he/she has published, a résumé or CV, and transcripts of any previous expert testimony in other trials, if available.

Fifth, the equine veterinarian should bring all documents and notes related to the expert opinion in the case. It is permissible for an expert to refer to these documents and notes while testifying if the expert cannot recall something during their testimony (the best practice is to ask the attorney if it is permissible to refer to the notes before answering in order to refresh recollection).

Sixth, an equine veterinarian should be confident in his/her testimony, but he/she should never make up an answer. It is permissible to admit when the expert does not know the answer to a question.

9. How to Handle Cross Examination

An expert should prepare for cross examination. The opposing attorney will typically attack an expert’s bias, the basis of the opinion, and lack of or reasonableness of alternative explanations. Cross examination from an opposing party is meant to destroy the credibility of the expert witness, reduce the expert’s likeability, or bolster the narrative of their case. For instance, a defense attorney in an animal cruelty case will often argue disease as a defense, not negligence of care; they may attempt to get the equine veterinarian for the state to admit that disease could have been a factor in order to bolster their theory of the case.

The expert should ask the prosecutor beforehand about the anticipated defenses that will be raised by the opposing party so that he/she can prepare for cross examination. The best way to prepare is to obtain a copy of the materials that the prosecutor received from the defense through the disclosure process. If the defense intends to question the expert using other scientific sources, those sources have to be disclosed, which gives the expert a chance to prepare. For example, a common technique is to attack the basis of the expert’s underlying opinion by using an alternative explanation found in a scientific treatise. Having a copy of this treatise beforehand will give the expert time to formulate a response and be prepared for questions concerning that treatise during cross examination.

Another common cross-examination technique is for the attorney to “box in the expert” by gaining only “yes” or “no” answers without clarifying explanations. The expert should remember that the
attorney offering the expert gets redirect (i.e., additional open-ended questioning after cross-examination), and will allow an expert to clarify or expound on answers that were elicited during cross-examination.

Overall, the equine veterinarian must maintain confidence in his/her expert opinion. If the equine veterinarian is confident, then the trier of fact will be confident in relying upon that opinion in making a decision; otherwise, the trier of fact may ignore the substance of the entire testimony. Many cross-examining attorneys will try to shake the expert’s confidence by getting the expert angry or flustered. An agitated witness appears confused, biased, or not forthcoming. This technique is also intended to make the witness defensive and argumentative, which reduces likeability. The best way to combat this technique is to remain calm and exceedingly polite; this will make the cross-examining lawyer look like a bully (which reduces the lawyer’s likeability).

10. Conclusion

The equine veterinarian is often the most vital witness in an animal cruelty case. Understanding the basics of the veterinarian’s role before and during the prosecution of an animal cruelty case will give the equine veterinarian a deeper understanding of legal procedures and confidence in the courtroom.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Declaration of Ethics.

Conflict of Interest

The Author declares no conflicts of interest.

References and Footnotes

3. Minn. Stat. § 343.20 subd. 3.
4. Minn. Stat. § 343.21 subd. 9(d).
5. Minn. Stat. § 343.20 subd. 9.
6. Minn. Stat. § 343.21 subd. 9(b).
8. Minn. Stat. § 343.21 subd. 9(a).
10. Minn. R. Proc. 9.01 subd. 1(4)(c).
11. Minn. R. Proc. 9.01 subd. 1(4)(a).
12. Minn. R. Proc. 9.02 subd. 1(2)(a) and (b).
13. Minn. R. Evid. 702 Advisory Committee Comment.
14. Minn. R. Evid. 701.
15. Minn. R. Evid. 704.
16. Minn. Prac. 11, Evidence, § 702.01.
17. Minn. Prac. 11, Evidence, § 702.01.
26. Minn. R. Evid. 703, Advisory Committee Comment.

“Where there is no citation, the information is based on the author’s 8 years of experience as a trial attorney and having used expert witnesses in numerous cases, including during animal cruelty prosecutions involving equines.

“The Sixth Amendment to the Constitution guarantees that, ‘[i]n all criminal prosecutions, the accused shall enjoy the right…to be confronted with the witnesses against him.’ See also Crawford v. Washington, 541 U. S. 36 (2004); State v. Caulfield, 722 N. W. 2d 304 (Minn. 2006) (scientific analysis of controlled substances only admissible if the defense had an opportunity to cross-examine the analyst).

“However, if the consulting expert discovers exculpatory evidence, then that information has to be given to the defense and may subject that expert to being a trial witness. Crawford v. Washington, 541 U. S. 36 (2004).

“Admissibility of expert testimony in the form of an opinion or inference otherwise admissible is not objectionable because it embraces an ultimate issue to be decided by the trier of fact.”

“A basis for the narrative objection.

“Judges are afforded a great degree of discretion in allowing expert testimony, and appellate courts often respect their decisions with regard to admissibility. Gross v. Victorian Station Farms, Inc., 578 N. W. 2d 757, 760–61 (Minn. 1998). However, certain types of expert testimony are subject to limitations, such as probability evidence in criminal cases (e.g., DNA test results, blood tests, paternity tests), and opinions about syndromes (e.g., battered woman syndrome, rape trauma, conduct of sex assault victims).

“For instance, in State v. Saldano, 324 N. W. 2d 227 (Minn. 1982), a rape counselor’s opinion on whether a rape occurred was not admitted because the trier of fact could assess whether a rape had occurred.

“Veterinarian testimony was admitted where the veterinarian had more than 15 years of experience, focused on dairy cows, worked with stray voltage, focused on literature, and understood the external stresses in milk production.

“[The medical expert] must have had basic education and professional training as a general foundation for his testimony, but it is a practical knowledge of what is usually and customarily done by physicians… that is of controlling importance.”

“Foundation,” when used as a legal term means, “The basis on which something is supported; esp., evidence or testimony that establishes the admissibility of other evidence.”

“Id. The United States Supreme Court Advisory Committee sheds some light on this: [A] physician in his own practice bases his diagnosis on information from numerous sources and of considerable variety, including statements by patients and relatives, reports and opinions from nurses, technicians and other doctors, hospital records, and X-rays. Most of them are admissible in evidence, but only with the expenditure of substantial time in preparing and examining various authenticating witnesses. The physician makes life and death decisions in reliance upon them. His validation, expertly performed and subject to cross-examination, ought to suffice for judicial purposes.”

Supreme Court Advisory Committee Note.

AAEP PROCEEDINGS / Vol. 62 / 2016 213
In a typical criminal case, the State gets three strikes and the defense gets five.

Reasons include if the potential juror is partial, has a felony conviction, has a physical or mental disability rendering him/her incapable of performing a juror’s duties, knows the accused, etc.

As noted earlier, expert witnesses are given leeway to instruct and educate.

Witnesses who are expected to testify are typically sequestered during the pendency of a trial, and cannot enter the courtroom unless the jury is out of sight. An expert should discuss this beforehand with the lawyer.

For instance, in a horse neglect case tried by the author, the defense claimed that the horses were not neglected, but rather had “Strangles.” Expert witnesses in these trials were prepared ahead of time to explain why neglect was the cause, not a disease (e.g., the experts were able to separate the symptoms of Strangles from the signs of neglect).
Working With Rescues to Establish Best Practices and Safety Nets for Early Problem Solving

Jennifer Williams, PhD

Veterinarians may work with rescue organizations to give back to the horse industry, to meet new clients, and to help horses. By helping rescue operations and facilities implement and maintain best practices, they can help alleviate equine suffering. Author’s address: Bluebonnet Equine Humane Society, PO Box 632, College Station, TX 77841-0632; e-mail: jenn@bluebonnetequine.com. © 2016 AAEP.

1. Introduction

In the past 10 years, the number of equine rescue facilities in the United States has rapidly increased. These rescues range from structured, tax-exempt organizations governed by a Board of Directors (BOD) to private rescues run by an individual or family. Most rescuers start out with good intentions: to help needy horses. Unfortunately, some rescuers do not utilize best practices for rescue and equine care, and they end up becoming part of the problem. Their horses are seized due to neglect, causing the horses unnecessary suffering and costing communities additional monies in investigations and court expenses.

In the past few years, authorities in multiple states have seized emaciated horses from rescue organizations and individuals who claim to have rescued the horses. The horses in these cases have suffered from a lack of food and water and insufficient veterinary care. In most cases, horses came from bad situations and simply were not given an opportunity to regain lost weight or find veterinary care, although in some cases horses actually lost weight while with the rescue organization.

Equine rescues can fail in their mission due for many reasons, but the primary reasons are poor understanding of nonprofit structure and management, lack of knowledge of equine care, insufficient funding, over commitment, and the inability to turn a needy horse away.

Although the American Association of Equine Practitioners, the Animal Welfare Institute and Humane Society of the United States, the University of California–Davis, and several other organizations have published guidelines for horse rescues, most rescue organizations are not aware of these standards and thus do not follow them.

Veterinarians can help alleviate the suffering inadvertently caused by well-meaning rescuers by working with these organizations to insure they follow good equine husbandry and nonprofit management guidelines. When local rescues become problem rescues, veterinarians can work with local
law enforcement; other veterinarians; and stable, sustainable rescue organizations to assist the horses.

2. Identifying Good Rescues

Good rescue organizations provide critical services to the horse industry and to their communities. They often take in horses no one else wants, they rehabilitate horses from neglect cases, they tame and train wild/unhandled horses, and they retrain abused horses and those with behavioral problems. They save local communities funds by helping law enforcement agencies to investigate neglect cases, educate owners about proper horse care to reduce neglect due to ignorance, and provide manpower and facilities for housing horses when seizures are necessary.

There is a great deal of variation in the size, mission, and structure of rescue organizations. Some house all of their horses at one or two facilities whereas other organizations house their horses at foster homes. Some organizations take in only a few horses each year whereas others take in over a hundred horses per year. Some rescue organizations have paid staff and others are completely volunteer run. Rescues may focus on a particular breed or type of horse, a particular source of horses (neglect cases, auction purchases, owner surrenders, etc.), or horses with specific needs (horses with behavioral problems, those with medical needs, etc.).

Rescues may be set up as a 501(c)(3), tax-exempt organization. To achieve 501(c)(3) status, the rescue must have a BOD, be incorporated in the state it operates in, and submit paperwork and a fee to the Internal Revenue Service (IRS). The rescue must submit annual reports to the IRS to maintain its status, and financial records of the organization must be open to the public. Donations made to 501(c)(3) organizations are tax-deductible.

Some rescuers decide to forego the 501(c)(3) status and instead operate as private rescues. They do not have to incorporate or submit reports to the IRS, and they do not have to maintain open books. Donations made to these rescues are not tax deductible, but the individuals running the rescue may be required to report income from the rescue (such as donations, adoption fees, proceeds from fundraisers, etc.) as personal income and pay taxes on it.

Regardless of the specific structure or mission, good rescue organizations share several traits.

Transparency

Good rescue organizations are transparent with their foundational documents. This includes their IRS Determination letter (which grants them 501(c)(3) status), annual form 990 (financial report to the IRS), bylaws, and articles of incorporation. They also have published policies that govern the details of how their organization operates: adoptions, foster home management, veterinary care, etc.

Although many rescues do not publish their physical location because they do not want drop-in visitors or horses abandoned at their gates, they do have accessible email addresses and phone numbers. They return calls and emails in a timely manner, although it may take a few days to return calls and emails given that many are operated by volunteers. Everyone should avoid rescues that do not return calls or emails in a timely fashion.

Good rescues also are transparent about the horses in their care. They provide the public with the number of horses that enter their program each year, are adopted out, are returned by adopters, and that died or were euthanized. They also provide information on where their horses come from (negligent owners, animal control transfers, owner surrenders, etc.). Veterinary records are available for potential adopters, and they are willing to disclose any health or behavior problems.

Good Husbandry

All horses at reputable rescues receive vaccinations recommended for their area, an annual Coggins test, annual dental care, routine de-worming, and routine farrier care. Exceptions can be made for horses that are too frightened or wild to treat. However, the rescue should have experienced handlers working with these horses to help them achieve a level of training that is safe for them and their handlers.

Illnesses and lameness should be diagnosed and treated in a timely manner. Good rescues are willing to have horses euthanized who cannot recover from illness or lameness on the advice of a veterinarian. Ideally, the organization will have a policy that governs the decision making on treatment and/or euthanasia. That policy should set the stage for managers of the organization to make pragmatic and humane decisions in these situations.

Good rescue provide hay, grain, and water of sufficient quality and quantity to help healthy horses maintain their weight and to help emaciated horses safely gain weight. They provide feed and feeding regimens tailored to each equine’s unique needs.

Good rescues may have skinny and ill horses at their facilities, and they may also have horses that are difficult to handle. They should be able to document how long the horse has been with the rescue and show that the horse is improving. They should have and follow a plan for physical rehabilitation and training for each horse in the rescue.

The facilities do not need to be state of the art, but reputable rescues have clean facilities with sufficient space for each equine. Fences are in good repair, and there is plenty of appropriate shelter available. The facilities are designed to avoid injuries to horses and to keep handlers and visitors safe.

Fiscal Responsibility

Running a rescue takes money, and responsible rescues have sound, sustainable finances. They maintain an annual budget and adjust the budget each year as needed. They receive funds from a variety
of sources, and they work hard to keep their expenses low while at the same time providing quality care to their equines.

Well-run rescues have savings to cover emergencies, and they are not constantly in crisis: threatening to close down or unable to feed the horses because of a lack of funds. They strive to expand their donor base, and they thank donors promptly.

Financial responsibility is not left in the hands of just one or two people: good rescues employ checks and balances to make sure money is being spent appropriately. The BOD should review and approve the annual budget. The person responsible for making deposits should be separate from the person responsible for writing checks. Someone other than the treasurer should review the financial records on a routine basis. More than one person should be on all bank accounts.

For rescues with paid staff, the salaries should be appropriate for the responsibilities and the location, but exorbitant salaries are a sign of problems.

Sound Adoption Policies
Unless the organization is a sanctuary where horses go to live out the remainder of their lives, one goal of reputable rescue organizations is to make good adoption matches. Before an organization puts a horse up for adoption, they make sure the horse’s veterinary and farrier care are current and that the horse’s training level is assessed. Good rescues disclose any known health, lameness, or behavioral problems. Good rescues are willing to take an adopted horse back if it does not work out for its adopter or if the adopter cannot keep his horse regardless of how long ago the horse was adopted. They also adopt horses out with no breeding contracts and follow up to insure that horses are working out in their new homes. Good rescues require adopters to sign an adoption contract, and they enforce their contracts fairly for all adopters.

Willingness to Learn and Improve
Good rescues know that they can always improve their operation, so they are willing to learn. They attend animal welfare conferences when available and seek education from reputable equine magazines, their farriers, and their veterinarians. They work with respected trainers and clinicians and seek training for their volunteers and foster homes.

Good Reputation
Finally, good rescues have a good reputation with others in their area. Veterinarians, farriers, law enforcement, animal control officers, feed store owners, and trainers know who they are. Their adopters and volunteers are happy, and they have repeat adopters and long-term volunteers. There is always some volunteer turnover in rescue as volunteers move, get busy with jobs or families, or lose interest in horses or rescue. However, excessive volunteer turnover is a sign of internal problems in the organization.

The leader of good rescues is qualified to run the organization. He or she is well-educated on equine care and training, and he or she seeks qualified advisories in areas of nonprofit management. The leader should have a good reputation with the volunteers of the organization and the public.

Commitment to Donors, Volunteers, and Horses
Good rescue organizations honor their commitment to their donors by using donated funds wisely. They compare prices on items and services to get the best price. They seek discounted or donated services when possible. When donors designate a gift be used for a specific purpose, it is.

Good rescue organizations honor their commitment to their volunteers. They make sure the work environment is safe and appropriate. They provide training or mentoring to volunteers, and they are willing to move volunteers to different jobs to help them find the best fit. They listen to volunteers and make adjustments to volunteer schedules and tasks as possible.

Good rescue organizations honor their commitment to their horses by making their care a priority. They follow reasonable standards of care and provide safe housing. They work with veterinarians to diagnose and treat illnesses, injuries, and lameness. If a horse is suffering and his pain cannot be reasonably relieved, they authorize their veterinarian to euthanize the horse.

3. Working With Existing Rescues
Veterinarians can help good rescues become even better organizations in several ways. One way is to provide discounted veterinary services when possible. No organization should expect or demand free or discounted veterinary services, but they appreciate veterinarians who offer discounts, even if only on occasion. Rescues have a responsibility to their donors to use donated money wisely and they have a responsibility to the horses at their facility now and those that need them in the future. Veterinarians who can help rescues through discounted or donated veterinary services help donations go further, enabling more horses to receive the help they need.

Some veterinarians offer a discount on their services to rescues they work with, and others set up a vaccination clinic where they offer free or heavily discounted vaccinations for the rescue horses 1 day per year. Veterinarians may also recommend that rescues they work with apply to receive vaccinations for their horses from the Unwanted Veterinary Relief Campaign.

Providing veterinary services is just one way veterinarians can work with rescues. They can also work with rescues that provide law enforcement assistance, serve on the BOD, serve on an advisory board, or work with rescues to educate the public on proper horse care.
When working with rescue organizations that assist law enforcement in seizing horses, the veterinarian may provide an expert opinion on whether a seizure is warranted based on the condition of the horse(s), may attend the seizure to assess and treat horses on site, and/or may assess the horses once they’ve been moved to a holding facility awaiting court. Expert witness testimony provided by veterinarians can be critical to a successful court case.

Given that good rescues are always willing to learn and improve, veterinarians can educate rescues about best practices in equine care. This may include offering suggestions on revisions to policy on standards of care, veterinary care, euthanasia, etc. as well as sharing information about the latest research in diseases, lameness, and refeeding.

For veterinarians who would like to get more involved in a rescue operation, there are two options: serving on the BOD or the advisory board. The BOD is the legally and fiscally responsible governance of the organization. It sets the policies and insures that staff (employees and volunteers) adhere to those polices. It hires or appoints the Executive Director, and it insures that the organization works toward its mission. The BOD is responsible for making sure the rescue has the funds needed to operate through setting a reasonable budget, participating in fundraising activities, and making an annual contribution to the organization. By serving on a rescue’s BOD, veterinarians can help devise and implement best practices for rescues and oversee the care the rescue’s horses receive.

BOD members have a responsibility to put the organization first in all transactions and to disclose any conflicts of interests to the organization. Because serving on the BOD carries legal responsibilities, anyone considering serving on a rescue’s BOD should make sure the organization carries directors and officers’ insurance.

The advisory board is a less-formal group of individuals who offer advice to the organization. They do not have the ability to make decisions about the governance of the organization, but they share their expertise with the BOD and Executive Director and may help establish or run programs for the organization. In general, serving on an advisory board is a less-formal and time-consuming option than serving on the BOD.

Veterinarians can work with rescue organizations to educate the public and help horses in their local communities. There are several ways to make this happen. Veterinarians can present information on proper horse care to the public at a rescue event. Veterinarians may donate or discount their time to put on low-cost vaccination and/or Coggins clinics. Rescues and veterinarians can partner to distribute information on good horse care at events in their area.

Veterinarians who would like to financially contribute to a rescue organization can do so with cash donations, gift certificates, or items for silent auctions, or by making a donation in the memory of a client’s horse.

4. Preparing a Safety Net
One of the best things a veterinarian can do to help prepare a safety net is to know the rescues in his/her area. They can look for local rescues online and ask clients, veterinarians, and other horse professionals for lists of local rescues and about individuals who foster for rescue organizations. Unless another veterinarian knows and has visited the rescue lately, the veterinarian should review the rescue’s website, talk to the rescue’s manager or executive director, and visit the rescue. He or she should check to see that the rescue adheres to the practices of good rescues (discussed above), and offer to help underperforming rescues improve their operation through educational opportunities.

Getting to know the law enforcement or animal control officers responsible for equine cases in the area is another important step in preparing a safety net. Veterinarians can offer to assist officers with neglect or abuse investigations at rescue facilities. When rescues are not providing proper care to the horses at their facility, veterinarians can work with officers to educate rescuers so that they can provide better care for the horses at their facility. If the rescuer is unable or unwilling to provide proper care, veterinarians can assist law enforcement in seizing horses if necessary.

When a veterinarian discovers a rescue that is not caring for its horses and is unwilling to make necessary changes, he or she needs to report the rescue to local law enforcement. Sometimes veterinarians are reluctant to do this because they fear repercussions or loss of business from existing clients. However, these poorly run rescues need to be reported as soon as they’re discovered, before they have a chance to acquire, and neglect, more horses.

Veterinarians can work with other veterinarians, rescues, and horse industry members to form a rescue coalition in their community. The coalition can serve several purposes. It allows the horse industry and veterinarians a chance to get to know and keep in touch with local horse rescues, allowing them to spot problems early on. The coalition can offer educational opportunities to horse rescuers, allowing them to improve their operations. The coalition can also work together to aid law enforcement agencies in large-scale rescues, when there are too many horses for any one agency or rescue to handle.

A local rescue coalition aids the rescues by offering educational opportunities and a chance to gain public trust. It allows veterinarians to give back to the horse industry and to protect horses in their communities. It can also serve to get the veterinarian’s name in front of potential clients (the rescue’s adopters, foster homes, and volunteers). The coali-
tion can save local communities money by aiding law enforcement with neglect cases.

5. Conclusion
Veterinarians can protect the health and welfare of horses living at rescue centers by identifying good rescues in their area, working with those rescues to insure that their horses receive proper care, and assisting law enforcement officers who receive complaints about rescue organizations. By doing this, veterinarians can prevent equine suffering at the hands of poorly run or overwhelmed rescue organizations.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Author declares no conflicts of interest.
How to Finance Practice Ownership

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1. Introduction
One of the most often discussed topics in the area of practice management is how does one finance the acquisition of a veterinary practice. In general, there are two sources of financing practice ownership. Internal financing involves the seller of an interest in a practice providing financing. External financing involves a buyer working with a source other than the seller to provide the financing necessary to purchase an interest in a practice. These external sources can include financial institutions such as banks or other external sources such as family members.

Ultimately, any financing source, whether external or internal, is going to use the cash flow from the practice as a source for the repayment of the financing they provide. This means that before any financing can be provided a buyer must be able to clearly identify how much money the practice is providing for its owners. Some practices struggle with clearly identifying how much money is being paid to the current owners that could be used to repay debt if a transfer or ownership were to occur.

2. Internal Financing
The internal financing of the acquisition of a veterinary practice typically involves the existing owner or owners selling a portion or all of their interest to existing associate veterinarians. The buyer signs a note to the seller as part, if not all, the consideration for the acquisition of the interest in the practice. This process involves several aspects including the valuation of the practice interest being acquired, the actual terms of the note the buyer is executing for the benefit of the seller, the readiness of the associate to become an owner, and the seller being “ready” to sell an interest in the practice.

Valuation is always a difficult subject but in an internally financed practice acquisition it can become even more difficult. It is more difficult due to the fact that there is no outside entity involved to help determine the value of the interest being transferred. This situation potentially exaggerates the differences that a seller and buyer may have regarding the value of the interest being sold. The typical seller in this situation may have founded the practice or at a minimum has owned it for a very long time and in all likelihood has become emotionally attached to the ownership of the practice and therefore may believe the practice is worth more than can be justified using generally accepted valuation methodology. Also, a seller may have not done any advance preparation and planning for a succession and therefore they may need to get more for the practice than it is worth in order to feel secure as they move into a phase of life where they will not be making a regular income. A buyer may not feel as though they can afford to purchase the practice be-
cause of existing student debt or other financial hardship. Sometimes potential buyers simply lack sufficient training and experience to take on the duties that come with ownership. Although most of these challenges have little or nothing to do with the actual value of the practice, it does have a very real effect on the perception of the value of the practice. Without assistance from an outside advisor, whether it be a bank, accountant, or consultant, all of these potential challenges to internal financing can become amplified and potentially derail what should be a great succession opportunity.

In an internally financed practice transfer, one must determine the actual terms of the note. These terms include interest rate, length of the note or term, frequency of payments, and security or collateral securing the note. In an externally financed transaction, the financial institution loaning the money to the buyer has a very established criterion for all of these factors. In an internally financed transaction it is easy for the terms of the note to vary with other factors. Most often, if a seller is getting the price they want they may give the buyer something other than commercially reasonable terms on the note. For instance, interest-free notes, or principal reductions for certain performance criteria. These types of arrangements only serve to complicate the transaction and typically lead to conflict down the road when the practice may not be doing as well. If the appropriate value is used, then commercially reasonable terms should be applied to the note and not present any financial hardship to either party.

Readiness of the seller and the buyer are equally important in an internally financed transaction as an externally financed transaction. In an internally financed transaction, however, a lack of readiness on either parties’ part may not be discovered until both parties are fully invested in the process and this might make it more difficult to terminate a potential transaction. Whereas, in an externally financed transaction there are more outside individuals involved that may be able to assess the readiness of the buyer and seller at an earlier stage in the transaction.

On the surface, internally financed practice acquisition seems to be easier and less expensive but may, in the end, prove to be more complicated, more expensive, and more difficult to actually accomplish. Should one want to entertain an internally financed transaction they should spend time and resources making sure the practice is fairly valued and the terms of the transaction are commercially reasonable.

3. External Financing
An externally financed practice ownership transaction involves the seller, buyer, and a financing source other than the seller. Typically, this third party is a financial institution such as a bank or credit union. Sometimes, however, this third party may be a friend or relative of the buyer. When an external source other than a financial institution is used, the transaction tends to take on more of the characteristics of an internally financed transaction because both parties tend to become less objective and there is not outside “voice of reason” involved in the transaction.

Generally speaking, financial institutions are willing to loan money for practice acquisitions when the potential transaction meets their criteria. These criteria vary by institution but generally include some type of valuation criteria, terms of the note, security for the note, and credit worthiness of the buyer. Most financial institutions want the after-tax cash flow of the business to be able to fund all of the future payments of the note within the given term of the note. The note term is typically 10 years or less and the typical note interest rate is stated as a certain number of points over the institution’s prime rate, depending on the credit worthiness of the buyer/borrower.

It is always prudent when working with a financial institution to explore your financial options with more than one institution. Typically, the big “national banks” will have an established criterion for financing practice ownership transactions. In fact, many of the big national banks and the big regional banks will have loan officers and departments within the bank that specialize in veterinary lending. Typically, the terms offered by the national and big regional banks seem to be better for the buyer/borrower than terms presented to the buyer/borrower from local financial institutions. Many times, however, if presented with the big bank term sheet, the local bank will meet or exceed the terms offered by the big bank. For this reason, it is always a good idea to explore financing with multiple financial institutions and have at least one big bank and one local bank involved in the process.

4. Financing and Cash Flow Are Connected
As you have read throughout this document, valuation is a key aspect to financing any practice ownership transaction. Whether financed internally or externally, the principal and interest of the note will be funded with profits distributed to the owners of the practice. Ultimately, cash flow determines how much any business is worth, including veterinary practices.

Prior to becoming an owner of a practice, a non-owning veterinarian working in the practice is simply paid for his efforts in the practice. This compensation of efforts can be stated as a percentage of that veterinarian’s production or a set salary. Recently there has been a trend away from a commission like, percentage of production compensation to a more fixed or flat salary. Even when one’s compensation for his efforts is fixed, it is still related, albeit less directly, to his production. A veterinarian who grosses $500,000 per year is probably going to be paid more, even if it is a flat amount, than a veterinarian who grosses $200,000 per year.
When one becomes an owner of a practice he is entitled to receive all of the excess cash flow created by that practice. This excess cash flow is typically less than the mere profits of the business because profits do not account for things such as debt principal repayment within the practice, or acquisition of additional equipment, real estate, or other capital expenditures. It is true that the owner gets paid last and if the ownership are not good managers there may not be much cash left over to distribute to them. An equine practice should be able to generate at least 10% of its gross revenue as cash flow distributable to the owners. A well-run, efficient practice with not much debt should be able to generate significantly more than 10% of its gross revenue as cash flow to the owners. The very best-run practices with little or no debt service could create in excess of 20% of gross revenue as cash flow to the owners. If a practice is distributing less than 10% then you must look more closely as to why and make sure all the owners are “on board” with the reasons the practice is not producing enough cash. Obviously, the more cash you distribute to the owners, the more valuable the practice and the more debt a potential buyer/borrower can “afford” to service with these cash flows.

One cannot overemphasize the importance of cash flow to practice acquisition finance. Value and therefore total financing available are factors of cash flow. The more cash flow, the more value. The more value, the more one can borrow to finance a practice acquisition.

5. Conclusion
Financing the acquisition of a practice is challenging in and of itself. The more you know and prepare ahead of time the smoother the process. When beginning the process, one should create a team of competent, experienced advisors who will provide the unbiased truth about a potential opportunity. Being prepared and listening to your team will help make what could be a stressful time more enjoyable and satisfying.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.
Nuts and Bolts of Succession Planning

John A. Chalk, Jr, CPA, JD, CFP®, ChSNC

Succession planning is the process of planning for the successful transfer of control/ownership from one generation of owners to the next. Over two thirds of small businesses started in the United States never make it to the next generation of ownership. Of the one third that make the transition from one generation to the next, another two thirds never make it to the third generation. All in all, less than 10% of all small businesses started make it to the third generation of owners. Succession planning is the key to increasing the probability of successfully transferring the ownership of a business from one generation to the next. Succession planning involves preparation: the preparation of the business, the preparation of the seller, and the preparation of the buyer. This paper will explore the nuts and bolts of succession planning as seen through the perspective of the business, the buyer, and the seller. Author's address: Chalk, Cullum & Associates, 121 Countryside Court, Southlake, TX 76092; e-mail: jachalk@chalkcullum.com. © 2016 AAEP.

1. Introduction

Before the ownership of any business, including a veterinary practice, can be transferred the business itself must be prepared and healthy in order for the transition of ownership to be successful. Preparing the business for succession involves making sure the books and records are clean and accurate, the employees are competent and performing their respective duties without excessive supervision or the need for additional training, and the finances of the business are steady and strong.

Accurate books and records help the seller understand what the business is worth and gives the buyer comfort that they have a good understanding of what the business is actually worth. Accurate books should include cash and accrual financial statements that are prepared at least quarterly. The statements that should be prepared include an income statement, balance sheet, and cash flow statement. The books and records should be a clear and accurate description of the business. Personal expenses of the owner that are contained in the books and records of the business should be clearly reported so that the next owner can understand what the business looks like without the current owner.

The financial statements should assist all parties with calculating the value of the business. Owners are paid in two ways. Owners that work in the business should be paid a fair wage for working in the business. In addition to the owners’ wages for working in the business, a business owner should also receive compensation for their ownership. This compensation is paid in the form of dividends or profit distributions. It is these distributions that form the basis for determining the value of any business. The more a business returns to its owners the more it is worth. Conversely, if a business is not returning much to the owners then the value of the business is minimal, unless there is some other reasonable basis upon which to base a determination of value.
2. The Seller
The seller must be prepared to sell their interest in the business. This preparation involves reviewing the seller's overall personal financial condition and determining whether a particular seller is prepared to sell. The seller must take into account that once they are no longer owners of the business they will no longer receive the benefits the business has previously provided them. Benefits such as salary and profit distributions are obvious but you must look closely at other benefits that the seller was receiving and make sure that the seller will have enough resources to use to afford to no longer receive anything from the business.

Some sellers may prefer to sell smaller parts of the business over time and gradually pass the ownership to the next owners. During this transition, the seller may continue to manage the business and be the majority owner until they are completely prepared to step of the business. At the point they are fully prepared, they may then complete the succession and sell the remaining ownership in the business.

3. The Buyer
Buyers must be prepared to become an owner. Many times people working in a business may want to invest in the business for which they work. However, investing in the business and owning a business are different. An owner is ultimately responsible for every aspect of the business. They decide who to hire, fire, how much to pay, how much to charge, what equipment should be purchased, as well as every other decision of the business. An investor might simply choose to sell their interest if they are not happy with the management of the business. Buyers in a succession plan must become owners and not merely investors.

Before a buyer begins to acquire interest in a business they should begin to review the financial statements and gather information regarding the business. In short, they should begin to act like an owner before they become an owner. There may be additional education that the potential buyer should obtain so they are equipped to become an owner when the time is right.

Both the buyer and seller will want to have a clear understanding of the entire succession plan if there is going to be a gradual succession. Typically, the buyer will start out being a minority interest holder. In these situations, it is important that the buyer and seller enter into a shareholder's agreement that covers how all the owners will be treated in cases where one of the owners wants or needs to get out of the ownership. The clearer you can make this agreement the less chance there is of misunderstanding down the road.

4. Conclusion
Succession planning is a process that takes time and a significant amount of planning. All the parties involved must be prepared in order for the transition of ownership to go smoothly.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.
Review of the Treatment of Hyperkalemia in Horses

Langdon Fielding, DVM, DACVECC, DACVSMR

Hyperkalemia is a life-threatening electrolyte abnormality that can be encountered in a field or hospital setting. Early recognition is important and many of the required treatments are routinely carried by equine practitioners. Intravenous fluids, calcium, and dextrose can be combined and administered to rapidly manage this condition. Author’s address: Loomis Basin Equine Medical Center, 2973 Penryn Road, Penryn, CA 95663; e-mail: langdonfielding@gmail.com. © 2016 AAEP.

1. Introduction

Hyperkalemia is a life-threatening potassium derangement that occurs in both adult horses and foals.1 Immediate treatment must be started in the field if the abnormality is severe. Research in other species suggests that some treatments recommended to treat hyperkalemia in horses may be less effective than previously believed.1 Equine practitioners should be aware of these new treatment algorithms that can be used for the management of hyperkalemia in both the field and hospital setting.

There are two major physiologic causes for hyperkalemia in horses: 1) failure of the renal system to remove potassium from the body, and 2) shifting of potassium from within the cells to the extracellular fluid. In adult horses, hyperkalemia can be caused by anuric renal failure, hyperkalemic periodic paralysis (HYPP), rupture of the urinary system (bladder, ureters, or urethra), or massive cellular destruction (rhabdomyolysis or hemolysis).1,2 In foals, anuric renal failure and urinary system rupture are the most common causes; however, cellular lysis can also be encountered.3 Hyperkalemia may be suspected based on the history of an underlying condition, the presence of clinical signs, or by laboratory confirmation. Measured potassium concentrations can be affected by storage or ambient temperature and therefore unexpected results should be confirmed.

Clinical signs of hyperkalemia may be mild but typically include muscle weakness.1 Electrocardiographic changes may be observed when plasma potassium concentrations reach levels as low as 6.2 mmol/L and include 1) tall or peaked T-waves, 2) flattened P-waves, 3) prolongation of the QRS complex, and 4) eventual asystole.4 Electrocardiogram (ECG) changes are not always present with hyperkalemia and their absence should not be used to exclude the diagnosis.

If hyperkalemia is suspected due to historical information (HYPP status, history of renal failure), clinical signs, or laboratory confirmation, treatment should be started immediately. Some cases (i.e., HYPP) can be resolved in the field whereas others may benefit from stabilization before transport to an intensive care unit. Even a small improvement in the degree of hyperkalemia may be life saving. The objective of this article is to describe the treat-
ment approach to hyperkalemia and to highlight recent changes that affect equine practice.

2. Materials and Methods

The emergency treatments for hyperkalemia are outlined below. Newer proposed changes to previous standard treatment recommendations are notedated (*).

Severe Hyperkalemia
Greater than 7.0 mmol/L and/or associated clinical signs and ECG changes.

Intravenous Calcium Borogluconate (23%)
Administer at a dose of 0.5–1 mL/kg. The dose can be diluted in a 5-L bag of isotonic crystalloid fluids and given over 30–60 minutes. Cardiac arrhythmias are possible if calcium is administered too quickly; however, more rapid rates may be necessary in life-threatening situations. Calcium administration will not significantly change the plasma potassium concentration but is used to mitigate the cardiac effects of hyperkalemia.5

The treatments for moderate hyperkalemia listed below should also be initiated for cases of severe hyperkalemia.

Moderate Hyperkalemia
Greater than 5.5 mmol/L and/or associated clinical signs and ECG changes.

Isotonic Fluid Diuresis*

Previous recommendations focused on the use of isotonic (0.9%) saline that did not contain any potassium. However, research suggests the acidifying effects of 0.9% saline can induce shifting of potassium from the intracellular to extracellular fluid space.6 This shifting of potassium may be more detrimental than a less-acidifying fluid that contains a moderate amount of potassium (5 meq/L). Administration of a commercially available acetate fluid at 4–6 mL/kg per hour can help induce a fluid diuresis and increase potassium excretion from the kidneys.

Intravenous Dextrose Administration

Intravenous dextrose can be administered at rates as high as 8–16 mg/kg per minute in emergency situations.5 A practical approach may be to add a 500-mL bottle of 50% dextrose to a 5-L bag of IV fluids that is administered over approximately 1 hour for an average 500-kg horse. More moderate rates of dextrose administration (1–2 mg/kg/min) may be appropriate for milder cases of hyperkalemia and may have less-detrimental effects associated with severe hyperglycemia. Dextrose administration improves hyperkalemia by inducing the release of endogenous insulin and causing a shift of potassium from the extracellular- to intracellular-fluid space.

Intravenous Insulin Administration

Regular insulin (100 units/mL) can be administered at 0.1–0.2 IU/kg per hour if used in conjunction with high rates of dextrose administration. In conjunction with the practical approach described above, 0.5 mL of regular insulin can be added to the same 5-L bag of isotonic crystalloid fluid containing 500 mL of 50% dextrose. This bag of fluids is administered over approximately 1 hour for an average 500-kg horse. As mentioned previously, insulin will help to move potassium from the extracellular-fluid space into the intracellular-fluid space.7 The author does not recommend the use of insulin in situations in which blood glucose cannot be monitored. The consequences of severe hypoglycemia are significant and can be more life threatening than the hyperkalemia.

Beta-Agonists*

The administration of beta-agonists (inhaled or IV) have been shown to decrease potassium concentrations in other species.8,9 Research is needed in horses, but it is likely that a similar response would be observed. Inhaled albuterol (180–900 μg) can be administered to horses for respiratory distress and may be a similar starting point for hyperkalemia. This medication can be administered rapidly and may be life saving when there will be a delay before starting other treatments. Similar to insulin, beta-agonists improve hyperkalemia by moving potassium from the extracellular- to intracellular-fluid space.

Furosemide

Once IV fluid administration has been started, furosemide administration (1 mg/kg) may help to improve potassium excretion from the kidneys. However, furosemide should not be administered to horses with dehydration until adequate volume restoration has occurred. In addition, furosemide should be used carefully in cases of renal failure because it could lead to further deterioration in renal function. Continuous rate infusion of furosemide may be a consideration if the medication is being used in a hospital setting.10

Sodium Bicarbonate*

Previous recommendations have advocated the early use of sodium bicarbonate to treat hyperkalemia. In clinical trials, the effects of sodium bicarbonate have been either nonexistent or significantly less than the treatments listed above.7,11 At this time, sodium bicarbonate should no longer be used as a first-line treatment for hyperkalemia but could still be considered for refractory cases when other treatments are not sufficient.

3. Results

Treatment of hyperkalemia is often transient and provides a bridge until the primary medical condition can be resolved. Cases of HYPP may resolve
quickly and long-term management can prevent future episodes. A ruptured bladder can be repaired surgically with an excellent prognosis. However, conditions with a more guarded long-term prognosis (acute renal failure) may show initial improvement only to relapse later. As a general rule, hyperkalemia will be easier to manage in horses with a functioning renal system than in those patients in which urine is not being produced.

4. Discussion
Equine practitioners can use the described treatment approach for the initial management of hyperkalemia. The simple combination of fluids and additives listed below is easy to create and can be life saving.

Practical Treatment of Equine Hyperkalemia

1. A 5-L bag of a balanced and isotonic crystalloid solution
2. Add 500 mL of 50% dextrose
3. Add 0.5 mL of regular insulin (100 units/mL)
4. Add 500 mL of 23% calcium gluconate

This fluid mixture can be administered in a quantity of 10 mL/kg over approximately 1 hour. Inhaled albuterol can be administered if IV fluid therapy will be delayed. For longer-term care, continued IV fluids with dextrose and insulin may be warranted as well as furosemide administration.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnote

aNormosol-R, Hospira, Inc., Lake Forest, IL 60045.
Double-Blind, Placebo-Controlled, Randomized Study of Dipyrone as a Treatment for Pyrexia in Horses

Emily Sundman, DVM*; Ming Yin, PhD; Tianhua Hu, PhD; and Melinda Poole, DVM, DABVP

This clinical study demonstrates that intravenously administered dipyrone is effective and safe in controlling pyrexia in horses. Authors’ address: Kindred Biosciences, Inc., 1555 Bayshore Hwy, Suite 200, Burlingame, CA 94010; e-mail: emily.sundman@kindredbio.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Dipyrone has been used as an antipyretic and analgesic in horses, but was not previously FDA approved for use in horses. It generally has minimal gastrointestinal adverse effects. The objective of the double-blind, placebo-controlled, randomized study was to evaluate the effectiveness and safety of dipyrone (INAD 012-513) to control pyrexia in horses under field conditions.

2. Materials and Methods
The study had two phases: a main effectiveness phase and a follow-on field safety phase. The effectiveness phase was a double-blind, placebo-controlled, single-dose, randomized study. The safety phase was an open-label, single arm, multi-dose, field study. Randomization was 3:1 (dipyrone:placebo). Dipyrone was administered at 30 mg/kg by IV injection. Horses were required to have rectal temperature ≥102.0°F to be enrolled.

3. Results
A total of 138 horses were enrolled into the study and 130 horses were determined to be evaluable for the effectiveness analysis. Responders were defined as a decrease in temperature ≥2°F or a temperature of ≤101.0°F 6 hours after dose administration. Seventy-six of 99 dipyrone-treated horses (76.8%) and 6/31 of placebo treated horses (19.4%) were responders (P < .0001). Post-treatment adverse events were mild and transient, with no notable gastrointestinal adverse effects noted; however, specific diagnostics for gastric or colonic ulceration were not performed.

4. Discussion
Dipyrone was effective in controlling pyrexia 6 hours after administration in nearly 77% of the treated horses. Treated horses were diagnosed with a wide variety of common infections. Dipyrone seemed to be safe and well tolerated in the horse.

Research Abstract—for more information, contact the corresponding author

NOTES
Acknowledgments
The study was supported by KindredBio as part of the new animal drug approval application to FDA. Given that this was a clinical study conducted as part of the new animal drug approval process and enrolled client-owned horses, informed owner consent was obtained prior to enrollment for each horse.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors are employees of KindredBio. KindredBio is currently seeking FDA approval of Dipyrone.
Comparison of Serum Amyloid A in Horses With Infectious and Non-Infectious Respiratory Diseases

Molly Viner, BS†; Melissa Mazan, DVM, DACVIM (LA); Daniela Bedenice, DVM, DACVIM (LA), DACVECC (Equine); Samantha Mapes, MS; and Nicola Pusterla, DVM, PhD, DACVIM (LA)*

Serum amyloid A (SAA) will be more reliably elevated with infections of the upper respiratory tract rather than noninfectious upper airway conditions. This can facilitate early detection of respiratory disease, help track disease progression, and aid practitioners in making recommendations about proper biosecurity and isolation of potentially contagious horses. Authors’ addresses: Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California–Davis, Davis, CA 95616 (Viner, Mapes, Pusterla); Department of Clinical Sciences, Cummings School of Veterinary Medicine at Tufts University, North Grafton, MA 01536 (Mazan, Bedenice); e-mail: npusterla@ucdavis.edu. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction

The acute phase protein serum amyloid A (SAA) has been shown to be a useful inflammatory parameter in the horse, given that it maintains low levels in health and increases as much as 1000-fold in response to inflammation. The goal of this study was to evaluate SAA responses in horses with infectious and noninfectious respiratory diseases as well as healthy, control horses.

2. Materials and Methods

Two hundred and seven horses were grouped into the following categories: equine influenza virus, equine herpesvirus-4, Streptococcus equi subspecies equi (S. equi ss equi), inflammatory airway disease (IAD), and healthy controls. SAA concentrations were determined for all horses on serum using a stall-side lateral flow immunoassay platform (StableLab).

3. Results

SAA levels were found to be significantly higher for infectious respiratory diseases (equine influenza virus, equine herpesvirus-4, S. equi ss equi) and horses with IAD when compared with control horses. There was a significant difference between viral and bacterial infections and IAD. Using a receiver operating characteristic curve, SAA values > 52.5 µg/mL showed 91% sensitivity and 95% specificity for an infectious etiology.
4. Discussion

Equine practitioners can use the stall-side SAA lateral flow immunoassay to distinguish between infectious and noninfectious respiratory diseases when clinical signs are equivocal early in disease. This can facilitate making recommendations about isolation of potentially contagious horses.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
A commercially available fecal occult blood test (FOBT) is not specific for the occurrence of equine gastric ulcers (EGUs), and should not be used for diagnosis of this condition. Authors’ addresses: PO Box 4018, Sunland, CA 91041 (Ramey); Chino Valley Equine Hospital, Chino Hills, CA 91709 (Murrell, Fischer, Brauer, Klohnen); Fielding School of Public Health, University of California–Los Angeles, Los Angeles, CA 90024 (Lee); e-mail: ponydoc@pacbell.net. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
This study assesses the utility of commercially available fecal occult blood test (FOBT)* for the diagnosis of gastric ulcers in a clinical population of horses.

2. Materials and Methods
Eighty-one consecutive horses of various ages, sexes, and breeds presented to a referral equine hospital were examined by gastroscopy for EGUs, and then tested with the FOBT. Exclusion criteria included younger than 6 months of age, external signs of bleeding around the face or mouth, racing or dental work in the 48 hours preceding gastroscopy, anthelmintic treatment in the 5 days preceding gastroscopy, colic surgery with an enterotomy, evidence of mild (grade 1) gastric ulceration, recent known ovulation. A FOBT test was performed on each horse after gastroscopy.

3. Results
Both fecal albumin and fecal hemoglobin tests have high sensitivity, that is, each test gives a positive result virtually every time a horse is tested, regardless of whether it has EGUs. However, each test has extremely low specificity in that when a horse does not have an ulcer, the tests are still positive most of the time. This results in a very low measure of association between the test and the diagnosis.

4. Discussion
The FOBT used in this study does not accurately diagnose EGUs. Given the potential costs of treatment, initiating treatment for gastric ulcers based on the FOBT used in this study is not recommended. At present, a confirmed diagnosis of EGUs still requires gastroscopic examination.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Footnote
*Succeeed®, equine fecal blood test, Freedom Health, LLC, Aurora, OH 44202.
IgM and IgG Response of Horses and Pony Foals After Vaccination for West Nile Virus and Eastern Equine Encephalitis

Frank M. Andrews, DVM, MS, DACVIM-LAIM*; Dylan Shannon, DVM; Pilar Camacho-Luna, DVM; Michael L. Keowen, BS; Frank Garza, Jr, MS; Alma Roy, PhD; Robert Keene, DVM; Steve Grubbs, DVM, PhD; Tristan Doyle, VME; and Sara Lyle, DVM, PhD, DACT

Vaccination with a commercially available multivalent vaccine containing West Nile virus (WNV) and Eastern Equine Encephalitis (EEE) did not result in IgM antibody titers 1:400 in horses and ponies. Therefore, vaccination for EEE and WNV using this product does not interfere with the currently used diagnostic testing for acute EEE or WNV infection. Authors’ addresses: Equine Health Studies Program, Department of Veterinary Clinical Sciences, School of Veterinary Medicine, Louisiana State University (Andrews, Shannon, Camacho-Luna, Keowen, Garza, Jr., Doyle, Lyle) and Louisiana Animal Disease Diagnostic Laboratory (Roy), Baton Rouge, LA 70803; Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO 64506 (Keene, Grubbs); e-mail: fandrews@lsu.edu. *Corresponding and presenting author. © 2016 AAEP.

Vaccination with a multivalent vaccine containing West Nile virus (WNV) and Eastern Equine Encephalitis (EEE) did not increase IgM titers >1:400, 7 days after booster vaccination in adult horses and after initial and booster vaccination in naïve pony foals. Therefore, vaccination does not interfere with serologic testing for naturally occurring WNV and EEE infections. Diagnosis of WNV and EEE virus is based on clinical signs and a >1:400 serum IgM titer. There is no reported information on the effect of recent vaccination on serum IgM antibody response in horses and foals and how recent vaccination might lead to a false-positive capture ELISA test for viral encephalitis. Six adult horses (ages 8–25 y) and six 4-month-old pony foals and their dams were used in the study. The horses and foals were vaccinated using a multivalent product containing killed WNV and EEE antigens to determine whether recent vaccination would lead to a false-positive Capture ELISA test for viral encephalitis. Six adult horses had a previous history of yearly vaccination, whereas the pony foals had not been previously vaccinated. The pony foal dams were vaccinated yearly, but were not vaccinated during this study and served as sentinels for WNV and EEE exposure. Blood samples were collected

Research Abstract—for more information, contact the corresponding author

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from the jugular vein of the horses, dams and foals on Days 0 (prior to vaccination), 7, 14, and 21 days after the first vaccination. Foals were given a booster vaccination and additional blood samples were obtained days 7, 14, and 21 post booster vaccination. Foals and dams were housed together in the same pasture. Horses were pastured separately. Serum IgM and IgG titers were measured at a commercial laboratory using Capture ELISA (MAC) tests and plaque reduction neutralization test (PRNT), respectively. All MAC-ELISA titers for WNV and EEE were negative at 1:400 for the study population. In the adult horses, PRNT titers ranged from 1:10 to >1:100 for EEE and >1:100 for WNV at all times. In the pony foals, PRNT titers to EEE and WNV ranged from negative to 1:10 prior to vaccine administration to >1:100 after the second vaccination. One foal had negative PRNT titers to EEE throughout the experiment. Vaccination with a commercially available multivalent vaccine containing WNV and EEE did not result in IgM antibody titers ≥1:400 in horses and ponies. Therefore, vaccination for EEE and WNV using this product does not interfere with current diagnostic testing for EEE or WNV using the MAC-ELISA.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
This study was funded by Boehringer Ingelheim Vetmedica. Drs. Keene and Grubbs are employees of Boehringer Ingelheim Vetmedica.

Footnote

aVetera Gold, Boehringer Ingelheim, St. Joseph, MO 64506.
Duration of Serum Antibody Response to Rabies Vaccination in Horses

Alison M. Harvey, BVSc, MRCVS; Johanna L. Watson, DVM, PhD, DACVIM; Stephanie A. Brault, DVM, PhD, DACVIM; Judy M. Edman, BS; Susan M. Moore, MS, MT, (ASCP) SBB, PhD; Philip H. Kass, DVM, MPVM, MS, PhD, DACVPM; and W. David Wilson, BVMS, MS, Hon DACVIM*

A rabies revaccination interval of more than one year may be indicated in specific horses. Authors’ addresses: William R. Pritchard Veterinary Medical Teaching Hospital (Harvey, Brault), The Department of Medicine and Epidemiology (Watson, Edman, Wilson), The Department of Population Health and Reproduction (Kass), School of Veterinary Medicine, University of California—Davis, Davis, CA 95616; Kansas State Veterinary Diagnostic Laboratory, Kansas State University, Manhattan, KS 66506 (Moore). Dr. Harvey's current address is Cedar Veterinary Group, Clifton Veterinary Surgery, Anstey Lane, Alton, Hampshire, United Kingdom GU34 2RH. Dr. Brault’s current address is Equine Veterinary Services of Northern Colorado, Laporte, CO 80535; e-mail: wdwilson@ucdavis.edu. *Corresponding and presenting and author. © 2016 AAEP.

1. Introduction
AAEP Vaccination Guidelines include rabies as a core vaccine against which all horses in North America should be revaccinated annually. In contrast, revaccination intervals of 3 years are recommended for the same inactivated rabies vaccines in dogs and cats, based in part on documentation of persistence of rabies virus neutralizing antibody (RVNA) titers at protective levels (>0.5 IU/mL) for a prolonged period. Similar data are not available for horses.

2. Materials and Methods
Forty-eight adult horses with undocumented vaccination status were vaccinated with one dose of an inactivated rabies vaccine. Serum samples were collected prior to vaccination, at 3–7 weeks post-vaccination, and at 6-month intervals for 2–3 years thereafter. RVNA levels were measured using rapid fluorescent focus inhibition test. Serological data from pre- and post-vaccination samples were used to predict which horses had likely been vaccinated previously and which were likely naïve. Duration of persistence of RVNA levels > 0.5 IU/mL, the level predicted to be protective, was assessed for both groups.

Statistical Analysis
A mixed-effects linear regression model was used to analyze RVNA levels for 2–3 years post-vaccination.

3. Results
All horses that were predicted to have been vaccinated previously maintained RVNA levels above 0.5
IU/mL for the duration of the study (2–3 y). There was no significant difference in the response to vaccination or duration of RVNA levels ≥ 0.5 IU/mL between horses <20 and horses ≥20 years old. RVNA levels ≥0.5 IU/mL persisted for >1 year in only one of the seven naïve horses.

4. Discussion
A rabies revaccination interval of more than 1 year may be appropriate in previously vaccinated horses, but not in naïve horses.

Acknowledgments
This study was supported by the Bernice Barbour Foundation and the Center for Equine Health, University of California, Davis, with funds from the Oak Tree Racing Association, the state of California pari-mutuel wagering fund, and contributions from private donors. Vaccine was kindly supplied by Merial, Inc. The T. S. and K. D. Glide Foundation, Davis, CA are acknowledged for their help in providing horses for this study.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Rabies vaccine was supplied by Merial Inc., Duluth, GA 30096.
Pharmacokinetics of Chloramphenicol at Steady State in Adult Horses

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When administered at a dose of 50 mg/kg by mouth every 6 hours, the highest reliably achievable mean inhibitory concentration (MIC) is 2.0 µg/mL when using average duration above MIC. Authors' addresses: Department of Medicine and Epidemiology, School of Veterinary Medicine University of California–Davis, Davis, CA 95616 (Estell, Patel, Edman, Magdesian); K. L. Maddy Equine Analytical Chemistry Laboratory, Davis CA 95616 (Knych); e-mail: krista.estell@gmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Chloramphenicol is routinely recommended for the treatment of a variety of bacterial infections in the horse. The recommended susceptibility breakpoint for chloramphenicol by the Clinical Laboratory Standards Institute is 8.0 µg/mL. The authors hypothesize that this level is not achievable in adult horses with the commonly prescribed dose rate of 50 mg/kg by mouth every 6 hours, and therefore a lower mean inhibitory concentration (MIC) should be targeted.

2. Materials and Methods
Seven horses were administered chloramphenicol palmitate tablets orally at a dose of 50 mg/kg by mouth every 6 hours for 16 doses. Blood was collected at regular intervals for analysis using liquid chromatography–mass spectrometry.

3. Results
The physical examination parameters were normal for each horse. Although 3/7 horses developed soft feces, no other adverse reactions occurred. If chloramphenicol was administered every 6 hours, 6/7 horses achieved adequate plasma concentrations for ≥50% of the dosing interval to target bacteria with a MIC ≥ 2.0 µg/mL. All horses had plasma concentrations ≥ 1 µg/mL for long enough to reliably target bacteria with a MIC ≤ 1 µg/mL.

4. Discussion
Clinicians who intend on using chloramphenicol should obtain a MIC for target bacteria rather than relying on laboratory interpretation according to Clinical Laboratory Standards Institute guidelines, which mistakenly categorize bacteria as susceptible to chloramphenicol based on an unachievable MIC in adult horses.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors declare no conflicts of interest.

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Computed Tomography and CT Myelography of the Equine Cervical Spine: 91 Cases

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Computed tomography (CT) and CT myelography of the entire cervical vertebral column is possible in full-size adult Warmblood horses. The technique provides excellent images of the cervical vertebrae and should be considered as an important diagnostic tool in horses with lesions of the cervical spine. Authors’ addresses: Evidensia Equine Hospital–Helsingborg, SE-25466 Helsingborg, Sweden (Kristoffersen, Lindgren, Lindegaard); Circle Oak Equine Sports Medicine and Equine Rehabilitation, Petaluma, CA 94954 (Puchalski); e-mail: mads.kristoffersen@evidensia.se. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Horses with neurological deficits, abnormal head/neck position, and obscure forelimb lameness are suspected to have lesions in the cervical spine. Computed tomography (CT) can image the cervical spine in three dimensions in superior anatomical detail.

2. Methods
In a retrospective case series, horses undergoing cervical CT and CT myelography from June 2013 to January 2016 were reviewed. The horses were examined in left lateral recumbency using intravenous anesthesia. A Big Bore scanner and a custom-made equine CT table were used.

3. Results
Ninety-one horses had cervical CT performed including 72 CT myelograms; 76 were Warmblood horses with average age, 6.8 years; average weight, 540 kg (maximum weight, 714 kg). In 70 horses, the cranial thoracic vertebrae were also imaged. Lesions detected using CT included osteoarthritis of the articular process joints, soft tissue lesions, fractures, and fragments. Spinal cord impingement and compression were demonstrated using CT myelography. More than 50% of the lesions were caudal to the fifth cervical vertebrae. Average anesthesia time was 56 minutes (SD, 10.5 min). No complications related to the procedure were observed.

4. Discussion
Cervical CT and CT myelography can be performed in large adult horses and have great potential to diagnose cervical lesions and guide therapeutic intervention. Further studies are needed.

Research Abstract—for more information, contact the corresponding author

NOTES
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Therapies for Equine Soft Tissue Injuries

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1. Introduction
Equine tendon and ligament injuries are commonly encountered in sport horses and in the general equine population. This paper will review current methods for treatment of equine soft-tissue injuries. Methods presented will include cold therapy, exercise protocols, regenerative therapy, therapeutic ultrasound, extracorporeal shockwave therapy (ESWT), and low-level laser therapy.

2. Initial Therapy for Acute Injuries
An accurate diagnosis with measurement of tendon/ligament and lesion cross-sectional area is imperative before initiating treatment for soft-tissue injuries. Quantitative measures obtained on sonograms allow for objective assessment of healing, help determine the rehabilitation exercise program, and identify the effect of other treatment modalities in use. Treatment of acute soft-tissue injuries should include the following: cessation of exercise, cold therapy, NSAIDs, and support bandaging to control swelling.

3. Cold Therapy
Cold therapy should be initiated immediately following injury and continued for 7–14 days. The major physiologic benefits of cold therapy are decreased local circulation, decreased pain, and reduced tissue swelling.1 These benefits are most effective early in the period following injury. The primary effect of local cold application is to constrict blood vessels and reduce tissue temperature. Reduced blood flow will reduce edema, hemorrhage, and extravasation of inflammatory cells. Cold reduces tissue metabolism and may inhibit the effect of inflammatory mediators and slow enzyme systems.2 Cyclical rebound vasodilatation is another response to cold therapy. Following a minimum of 15 minutes of cold therapy that reaches tissue temperatures from 10–15°C, cycles of vasoconstriction and vasodilatation occur. Vasodilatation associated with cold therapy may help further resolve tissue edema.

Cold immersion of the distal limbs is also effective in reducing severity of laminitis by decreasing the activity of laminar matrix metalloprotease (MMP) and causing laminar vasoconstriction when applied during the developmental phase.3,4 Cold may be applied by ice-water immersion, application of ice packs or cold packs, and ice water–charged circulating bandages or boots. The most beneficial therapeutic effects of cold occur at tissue temperatures between 15 and 19°C (59–66°F).2 Direct contact of ice water with the skin is the most effective method of cold therapy. Buckets or turblulator boots may be used depending on the site. Recently, a study identified a simple way to effectively cool the distal limb using a bag-within-a-bag technique.5 Empty 5-L fluid bags are place on the
distal limb and secured with ice between the bags. Ice-water immersion of the equine digit for 30 minutes resulted in significant decreases in laminar temperatures. Vascular perfusion decreased, but not significantly. Cold therapy is indicated in acute injuries to reduce edema, slow the inflammatory response, and reduce pain. It is particularly effective during the first 24–48 hours after injury. Cold should be applied for 30 minutes three or four times daily during the acute phase of injury. This modality is also very useful to apply to the injury site following rehabilitation exercise during the convalescent period.

4. Exercise
Controlled exercise remains the most important methodology for rehabilitation of soft-tissue injuries. Exercise is necessary to align the newly synthesized collagen fibrils along the lines of stress in the limb. Without the addition of controlled stress to the injured ligament or tendon, the lesion would heal with disorganized scar. Exercise is slowly increased as indicated by interpretation of sequential ultrasound and lameness examinations (Table 1). Hand walking for 5–10 minutes once or twice daily (depending on lesion severity) should begin very soon after injury to encourage optimal fiber alignment and prevent restrictive adhesions. Ultrasound and lameness evaluations should be repeated every 8–10 weeks and exercise levels may be increased as parameters improve. According to Gillis, controlled exercise alone resulted in successful outcomes for 67–71% of horses with soft-tissue injuries. Pasture turn-out resulted in successful outcomes in 25–51% of horses.

All exercise must be adjusted for the level of soundness. If there is increased lameness, swelling is noted at the injury site, or ultrasound parameters deteriorate, the exercise level must be decreased. Work at the trot should only begin after a solid 10–15 minutes of hand walking for warmup. Initially, time at the trot should be broken into short 1–1.5-minute segments.

5. Regenerative Therapy
Regenerative therapy is a common term for the use of biological agents to repair and restore damaged tissues. The ultimate goal for use of these modalities is to improve the quality of repair. Regenerative therapies include stem cells derived from sites such as bone marrow and umbilical cord, fat-derived regenerative cells, platelet-rich plasma (PRP), and autologous conditioned serum (ACS). These techniques enhance matrix and collagen production, recruit stem cells, and enhance cytokine levels. ACS contains the anti-inflammatory cytokine IL-1 receptor antagonist protein and down-regulates inflammation. ACS also contains cytokines that promote healing such as TGF-β, PDGF, IGF-I, and VEGF, among others.

In a placebo-controlled study of experiment equine tendinitis, a single intralesional injection of PRP was found to result in increased collagen, glycosaminoglycans, and DNA content compared with controls. The tendons treated with PRP also had higher strength and improved elastic modulus. The PRP tendons had enhanced collagen organization and increased metabolic activity. This study is very strong evidence for the positive effects of PRP for treatment of equine soft-tissue injuries. PRP has high levels of PDGF and TGF-β, among other cytokines. Growth factors such as IGF improve equine tendon healing in vitro and in vivo. TGF-β enhances collagen production in cultured equine tendon cells.

Injection of stem cells to treat a soft-tissue lesion via intralesional, IV, or intrarterial approaches was originally hoped to result in healing with tissue characteristic of the original tendon or ligament. Additional effects of stem cells include stimulation of local vasculature, release of a variety of cytokines that enhance healing, inhibition of T and B lymphocytes and killer-T cells, and recruitment of local stem cells.

PRP and stem-cell sources may be autologous or allogeneic. Allogeneic products permit rapid treat-
ment without the necessary lag for obtaining a sample, processing, or proliferation of cells. Allogeneic PRP and stem cells have been used in horses and found to be safe and effective. PRP or stem cells are injected 21–30 days after injury or at a time when other therapies have not been effective in resolving the lesion. The horse is often administered a single dose of parenteral antibiotics such as ceftiofur (2.2 mg/kg IV). The site is aseptically prepared and regional anesthesia is used to desensitize the area of injection. The injections are usually placed with ultrasound control. A sterile bandage is applied and left in place for 2 days. Following injection, the horse is confined and only allowed hand grazing. Bandaging is continued for 2 weeks. At 2 weeks following injection, the in-hand exercise regimen that was being used before injection is resumed. Follow-up ultrasound and lameness evaluations are made approximately 30 days later.

In the author’s practice, PRP is used to treat moderate to severe soft tissue injuries. Stem cells are used to treat moderate to severe injuries that include considerable tissue loss. Either modality is used to treat lesions that have failed to continue healing regardless of the original treatment method used. Most horses are treated with only one injection of PRP or stem cells.

6. Therapeutic Ultrasound

Therapeutic ultrasound (US) is useful for treatment of soft-tissue injuries. The modality may be used between ESWTs or used on its own.

Therapeutic ultrasound selectively heats tissue with high protein/collagen content. The most intense heating occurs at tissue interfaces. Equine muscle does not heat to the same degree as dog muscle treated with US. However, equine tendons and ligaments are heated substantially when exposed to therapeutic US. As reported by Montgomery et al., superficial digital flexor tendon (SDFT) mean temperature increase was 3.5°C and 2.5°C in the deep digital flexor tendon (DDFT) following 10 minutes of treatment at 1.0 W/cm². In the 1.5 W/cm² treatment group, mean temperature increase was 5.2°C in the SDFT and 3.0°C in the DDFT.

Increased tissue temperatures enhance tissue metabolism and likely increase local circulation. Both of these effects of therapeutic US support tissue healing. An additional benefit of therapeutic US is the deep massage of tissues caused by the sound waves referred to as cavitation and streaming of fluids and ions. These nonthermal effects result in compression and expansion of tissues and tissue fluids that may improve tissue healing. Fibrous connective tissue scars may be more effectively stretched following heating with therapeutic US.

Treatment is usually performed once or twice daily for 10 to 14 days. Hair must be clipped, the skin cleaned with a moist cloth, and US-coupling gel must be applied to provide good contact between the transducer and the skin. In horses, treatment for most superficial tendon or ligament injuries is conducted with a 3-MHz transducer at 1 W/cm² for 10 minutes twice daily.

Low-intensity US may be applied for 2–3 hours of treatment for acute injuries and 4–6 hours once daily for chronic injuries. A commercially available low-intensity ultrasound device has output permanently set at 2.75 MHz at 0.85 W/cm². For accessible anatomic locations, the device is placed on the limb for the appropriate treatment time.

7. ESWT

ESWT results in reduced levels of inflammatory mediators, increased collagen production, small vessel proliferation, growth factors, and recruitment of stem cells. Improved outcomes in equine suspensory desmitis have been reported following ESWT. The pressure-tension gradient of the sound energy pulse is responsible for the biological effects. Most ESWT is conducted between 0.25 and 0.45 mJ/mm². Low-level ESWT energy provides the most beneficial regenerative effects to tissue.

The full course of treatment consists of three to five ESWT applications at 2–3-week intervals. The most common settings for treatment with a focused shockwave device are 1500–2000 impulses, energy at 0.25–0.4 mJ/mm², focused at the depth of the lesion. ESWT is often the primary treatment modality for many soft-tissue injuries.

8. Laser Therapy

Low-level laser therapy is beneficial for wound therapy, pain reduction, and healing of soft-tissue injuries. The biological effects of laser identified in research settings include release of endorphins, blocking of pain sensation through reduced nerve depolarization, enhanced adenosine triphosphate (ATP) production, and reduced IL-1 levels. In a rat model of Achilles tendinitis, laser therapy improved tendon strength and reduced inflammatory cytokines more than treatment with diclofenac. Laser light energy is optimally absorbed through the skin at wavelengths of 805–980 nm. The dose of energy required for treatment depends on the nature of the injury, depth of the tissue, and desired effect (biostimulation or anti-inflammatory/pain relief). A recent study by Haussler found laser combined with chiropractic therapy to result in more pain relief for equine back pain than laser or chiropractic alone. Recommended treatment dose ranges from 4 to 12 J/cm². The most challenging issue with laser treatment is delivering an effective dose to the target tissues. Absorption and dispersal of the laser energy by the skin, hair, and deeper tissues significantly reduces the energy at the treatment site.
9. Conclusion

With the wide variety of treatment modalities available for treatment of soft-tissue injuries, choices must be made based on the level of injury, expectations for results, and cost factors. The most important approach for care of soft-tissue injuries remains restriction from free exercise, repeated characterization of the lesion (usually via lameness evaluation and sonography), and initial anti-inflammatory treatment (cold therapy and medication). This is followed by appropriate rehabilitation exercise. For mild injuries, conservative therapy, as outlined above, is appropriate and entails modest cost. For more serious injuries, or for injuries that have stopped progressive healing, ESWT, PRP, or stem cells are recommended to stimulate the healing response. Regenerative modalities have moderate-to-high costs to the client. At this point, direct comparison of treatment response to the various modalities reported here are not available.

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Declaration of Ethics

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References and Footnote


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Rehabilitation Directed at Maintaining or Treating Restricted Joint Motion in the Horse

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1. Introduction
The goal of a rehabilitation program is to return the horse to its previous level of fitness and function in the shortest amount of time. In humans there are many studies that have been performed that have demonstrated efficacy of many modalities or techniques for specific conditions. However, in the horse there is less information available in the form of evidence-based medicine. There is little work in the equine to validate the efficacy of different therapeutic modalities. Many of the treatments have been adapted from humans for which there is better evidence of efficacy. There is no reason not to use modalities that have been demonstrated to be efficacious in the human; however, efficacy determination must still be done in the equine.

2. Therapeutic Plan Development
It is important not use a “shotgun” approach when developing and implementing a therapeutic plan. Also, rehabilitation is a team approach consisting of the veterinarian, therapist, owner, as well as other professionals. All members of the team need to be informed and “on board” to insure the best possible outcome.

There are several items that must be considered when developing a rehabilitation program for an individual. First, what has been your success with patients with a similar condition and how have they progressed during the treatment? Second is the establishment of outcome goals, such as what should be the patient’s progress during the rehabilitation process? Third, determine your capabilities and the resources you have available. Lastly, patient assessment is performed to determine nature of the injury, type of therapy or surgery that has been performed, patient disposition, and what owner expectations are. You then develop a plan for the patient based on the answers to these questions.

The stage of the injury will affect the type of plan developed. The initial stage is from the time of injury or surgery until all inflammation has resolved. The goal of therapy during this stage is decreasing pain and inflammation, preserving range of motion, and prevention of muscle atrophy. Typically, cold therapy, low-level laser therapy, supportive wraps, and passive motion is used in this period.

The second stage starts when inflammation is resolving. During this stage you need to gradually increase the stress that the healing tissues are subjected to. You are trying to prevent scar tissue from developing or revising it. Therapies include
therapeutic exercise, aquatic therapy, therapeutic ultrasound, shockwave, as well as others.

Which modality to use in which stage is dependent upon one’s expertise, available resources, and what you are trying to accomplish.

3. Therapeutic Monitoring
It is important to develop methods for measuring the response of the condition to therapy. You should try using quantifiable methods. Simple methods are available. For instance, tape measures may be used to measure limb circumference, goniometers can be used to measure joint angles, and pressure algometry may be used to measure decreasing pain in an area. Other methods include diagnostic imaging, thermography, or Lameness Locator.

Measurements should be taken at the onset of therapy and at set intervals. Early in the therapy evaluations, they may need to be performed daily or weekly, whereas later they may need to be done monthly. If the condition worsens or no improvement is noted during therapy, the plan should be modified.

4. Facilities, Equipment, and Personnel
When developing a rehabilitation practice it is important to read the State Veterinary Practice Act. Most states consider performing animal rehabilitation as the practice of veterinary medicine. If a person is not a veterinarian then they will need to be a full-time employee of a veterinarian or horse owner. The level of supervision required will need to be determined, if an individual is a full-time employee of a veterinarian. Most states allow a licensed veterinary technician to work under indirect supervision. However, laws vary from state to state and should be reviewed for the state in which a person is working.

Individuals developing rehabilitation plans, performing therapies, and monitoring progression should be thoroughly trained. This training should be more in depth than the technical service training usually received when purchasing equipment. There are advanced training courses available or they can spend several weeks at an equine rehabilitation center. A major problem in the field of equine rehabilitation is lack of formal education and training. In some cases, therapies are provided that are of little benefit or may be detrimental. Advanced training is available for equine rehabilitation, hyperbaric oxygen therapy, chiropractic, and acupuncture, to name a few.

The demographics of the area must be evaluated before establishing a rehabilitation service. The concentration of horses in the area needs to be determined. The equine disciplines, types of clients, and other rehabilitation facilities in the area are a few other items that should be considered.

They type of rehabilitation service offered is important. An ambulatory practice will limit the type of equipment and service you can provide. Ambulatory service will be limited to equipment that can be easily transported and therapeutic exercises. A rehabilitation service at a brick-and-mortar facility will be able to provide a wider range of therapies.

Equipment needs will depend on all the factors presented above. For an ambulatory service, equipment that should be considered includes therapeutic ultrasound, therapeutic laser, thermal therapies, shockwave therapy, and equipment to perform therapeutic monitoring. For a haul-in facility, equipment in addition to that mentioned above includes underwater treadmill, swimming pool, a cold-salt therapy unit, whole-body vibration, and pulsed electromagnetic therapy, to name a few.

All of the above equipment need not be obtained initially, but future needs should be anticipated. For instance, if funds are not available to purchase an underwater treadmill, one should still plan for one in the future. Location and housing of the equipment need to be planned for. Most equipment is expensive, ranging from several hundred dollars to several thousand dollars. In addition to the purchase price of the equipment, one must account for maintenance cost. In determining the charge for a service, this should be taken into account in addition to the time it takes to perform the therapy, as well as appropriate fee setting. If you have a low number of cases then you may have to charge a significant amount to recoup the expenses. That is why it is extremely important to determine whether the service area can support the equipment prior to purchase.

5. Nutrition
Nutrition is important rehabilitation. Painful horses that are in the process of healing have specific nutritional requirements. Horses are prone to development of gastric ulcers. Things to consider include the feeding of a non-grain-based diet and alfalfa hay. The obese horse may only need grass hay and a ration balancer. Horses that are in a catabolic state may require additional calories. Finally, all horse should have fresh water and a salt block.

6. Patient Environment and Mental Status
During therapy one should not neglect the rest of the patient. We often successfully treat the injury but lose the use of the horse due to other problems that arise. Providing a good environment, good nutrition, and supporting other limbs are oftentimes as important as the treatment itself. Do not neglect the mental status of the horse. Mental stimulation is needed if long period confinement is required.

7. Manual Therapies for Joints
Manual therapies include massage, stretches, and tissue mobilization. These help by restoring optimum joint movement by reducing adhesions, mobilizing joint structures, and enhancing joint movement, hyperbaric oxygen therapy, chiropractic, and acupuncture, to name a few.
lubrication and joint nutrition. They may be used in both the acute or chronic condition.

Stretching and Massage

Stretching and massage can increase blood flow, alleviate muscle spasms, mobilize scar tissue, and aid lymphatic drainage. They also provide pain relief from tight muscles and connective tissue that impinge on nerves, aid in restoration muscle length after injury, and decrease stiffness-related inactivity. Static or passive stretching consists of stretching a muscle to its limit and then maintaining or holding the stretch in that position. The desired motion and positioning are controlled and are not under control of the horse. It is unknown how effective stretching is. In a group of horses, Rose et al. found no improvement in stride length after several weeks of stretching. They did, however, find differences in joint range of motion between treatments in the shoulder, stifle, and hock. They concluded that frequency of application of passive stretches seems to have some influence on horse movement, but their research did not demonstrate consistent improvement. They also highlighted the possibility that stretching on a daily basis may be contraindicated and suggested that stretching three times per week may be safer.

The rationale for massage is supported by human research indicating that it may affect certain physiologic systems in addition to cellular and fascial components of the muscular system. Equine massage uses techniques first developed in humans that have been reported to increase range of motion, reduce activity of pain receptors, and reduce stress responses. However, the evidence in the horse is weak other than suggesting that massage is of any benefit other than promoting lymphatic drainage. Only one study could be found that indicated that massage to the caudal limb muscles increased passive and active limb protraction.

Mobilization

Mobilization is aimed at pain relief, restoration of normal joint biomechanics and nerve function, and improved muscle function. It is used to treat joint dysfunction that limits the range of motion by addressing altered mechanics. Factors that may influence joint mechanics include pain, joint hypomobility, joint effusion, contractures, fibrosis of the joint capsule or periarticular ligaments, and degenerative joint disease. Passive mobilization is used for increasing range of motion or decreasing pain. It is applied at varying speeds, amplitudes, or rhythm. The force is light enough that the horse can stop the movement. Active mobilization is an active joint movement that is carried out and controlled by the horse.

The majority of mobilization studies in the horse have been directed toward the axial skeleton. Clayton et al. found that the degree of bending in parts of the cervical vertebral column differed among the active mobilization exercises. As the horse’s head moved further caudally, bending in the lower cervical and thoracolumbar regions increased. This suggests that bending in the more caudal positions may be effective for activating and strengthening the core musculature that stabilize the horse’s back. Clayton also found that active mobilization performed in cervical flexion aids in mobilizing the cervical and thoracic intervertebral joints. Haussler et al. found that passive vertical mobility of the trunk varied from cranial to caudal. In another study, chiropractic manipulation of the spine increased dorsoventral displacement of the trunk. They concluded that this is indicative of producing increased passive spinal flexibility in actively ridden horses.

Based on the human literature, it has been recommended that mobilization for most injuries and post surgery can begin within 3 days. Careful protocols must be followed through. For severe ligament and tendon injuries, mobilization can begin at 3 weeks post injury.

8. Thermal Agents

Heat and cold may be administered to horses using many modalities that can range from applying cold water from a hose to deep-heating ultrasound technologies.

Cold

The main benefit of cold therapy is to decrease circulation, lower cell metabolism, prevent secondary tissue damage, decrease edema, and decrease pain. It is most effective early following injury or surgery. The primary effect is to constrict blood vessels. This reduction in blood flow reduces edema, hemorrhage, and extravasation of inflammatory cells. The lower cell metabolism decreases the effect of inflammatory mediators and slows enzymatic systems.

Cold therapy is indicated for acute injuries or inflammation and after surgery to reduce edema, slow inflammation, and provide analgesia. Cold is particularly effective during the first 24–48 hours after injury or surgery. Cold may be applied by ice water immersion, application of cold packs, cold salt water hydrotherapy units, and ice water circulating boots.

Studies have documented tissue effects of cryotherapy in horses. The influence of hypertonic cold water (5–9°C) spa bath hydrotherapy on the response of 27 horses with various lower leg injuries has been reported. Fifteen horses with superficial digital flexor (SDF) tendinitis and four with suspensory ligament desmitis that were treated for 10 minutes, three times a week responded with improved ultrasonographic echogenicity of injured tissues. Of these 15 horses, all but two returned to compete successfully within 6 months without re-injury. Petrovo et al. reduced the core temperature of the SDF tendon to 10°C after 1 hour using a...
commercial compression splint with circulating coolant. This indicated that topical application of cold can reduce core SDF tendon temperature in standing horses and that the temperatures achieved during treatment were not detrimental to the viability of the cells. Cold immersion of the distal limbs has also been shown to be effective in reducing the severity of laminitis by decreasing the activity of laminar metalloproteinase MMP and causing laminar vasoconstriction.19,20

Heat
The benefits of heat include increased circulation, muscle relaxation, and increased tissue pliability.21 When tissue blood flow is increased, metabolites are mobilized, oxygen levels are increased, and the metabolic rate of cells and enzyme systems are increased. The metabolic rate increases two to three times for an increase of 10°C. Increases in blood flow and vascular permeability can promote tissue edema resorption. Heat can also decrease pain via similar mechanisms to cold therapy. Tissues are more effectively stretched after warming. Heat therapy can be used to increase joint and tendon mobility. Heat is usually applied after the acute inflammatory period has ended.

Heat is commonly applied using hot packs. Deep heat may be applied using therapeutic ultrasound. Most of the physiologic effects of heat occur when tissue temperatures are raised to between 40 and 45°C.21 Tissue temperatures above 45°C may result in tissue damage.21 To achieve heating of deeper tissues to the therapeutic range, constant heat must be applied for 15–30 minutes. Kaneps21 found that tissue temperature changes due to warm water hose therapy ranged from 3.7 to 10.8°C. Temperature elevation is short lasting and depends on the distance to the surface, with limited effect on tissues deeper than 1.5–2 cm below the skin surface.21

Using therapeutic ultrasound, Montgomery et al22 found that the SDF tendon and deep digital flexor tendon (DDFT) are heated to a therapeutic temperature using a frequency of 3.3 MHz and intensity of 1.0 W/cm². However, the epaxial muscles are not heated to a therapeutic temperature using a frequency of 3.3 MHz and an intensity of 1.5 W/cm².22

9. Low-Level Laser Therapy
The low-level laser uses an intense beam of light to stimulate the body’s processes. It is reported to activate waste removal, increase repair activity, relieve swelling, heal skin wounds, and stimulate the blood and lymphatic systems.23–25 It has been reported to increase serotonin.23–25 It has been reported to have biostimulating effects such as acceleration of cell division, increase in leucocytic phagocytosis, stimulation of fibroblastic activity, and enhancing regeneration of lymph and blood vessels.23–25 Studies have shown it can cause vasodilation.23–25 All of these effects can assist healing and provide some relief of chronic pain when properly applied.

Lasers are divided into safety classifications in the United States by the American National Standard Institute. Class 1, 2, and 3a have low power output and are not used for therapeutic purposes. These will not be presented.

Class 3b lasers cannot emit an average radiant power greater than 0.5 W for an exposure time equal to or greater than 0.25 seconds or 0.125 J for an exposure time less than 0.25 seconds for wavelengths between 0.18 and 0.4 μm, or between 1.4 and 1 mm. In addition, lasers between 0.4 and 1.4 μm exceeding the Class 3a accessible emission limit (AEL) cannot emit an average radiant power greater than 0.5 W for exposures equal to or greater than 0.25 seconds, or a radiant energy greater than 0.03 J per pulse. Class 4 lasers and laser systems exceed the Class 3b AEL.

There is little research on the use of low-level laser therapy (LLLT) in the equine. Berg et al26 found superficial morphological changes in equine epidermis after treatment with 91 J/cm² of defocused CO₂ laser and severe changes with a homogeneous eosinophilic acellular zone of underlying dermis and a significantly thinner epidermis, when irradiation doses of 450 J/cm² were applied. Berg et al27 also found that irradiation with defocused CO₂ laser causes a moderate-to-vigorous heating effect in superficial tissue and a marked increase in blood flow. This increase in temperature could increase the risk of thermal injuries to the skin.27 The results also suggest that treatment with defocused CO₂ laser is not statistically better than placebo at reducing the grade of lameness in horses with traumatic arthritis of the fetlock joint.27 Ryan et al28 found that laser-light transmission was not affected by individual horse, coat color, or leg. However, it was associated with leg condition. Tendons clipped dry and cleaned with alcohol were both associated with greater transmission of light than the unprepared limbs. The use of alcohol without clipping did not associate increase laser light transmission. They recommended that the area treated should be clipped and cleaned beforehand.

The wavelengths of light used for LLLT fall into an “optical window” at red and near-infrared (NIR) wavelengths (600–1070 nm).29 Wavelengths in the range 600–700 nm are used to treat superficial tissue, and longer wavelengths in the range 780–950 nm, which penetrate farther, are used to treat deeper-seated tissues.29 Wavelengths in the range 700–770 nm have been found to have limited biochemical activity and are therefore not used.29

The most common method of determining laser therapy dosage is to measure the density of energy applied to the surface. This is typically expressed in J/cm². Variation in clinical effects can be observed at very high (>50 W) or very low (<1 W) power settings using the same J/cm² dose. The dose required for a particular condition is dependent
on the equipment used and what its wavelength is. As a general rule, the more superficial a tissue the less energy required.

In our practice, the most common use of LLLT is to decrease pain and inflammation associated with musculoskeletal injuries and for wound healing.

10. Mechanical Agent
This group includes therapeutic ultrasound, shock-wave, and devices such as whole-body vibration units.

Therapeutic Ultrasound
Therapeutic ultrasound is a form of acoustic energy used to treat musculoskeletal injuries. It offers deeper heating without excessive heating of the skin. Ultrasound can also be used to decrease pain and muscle spasm, promote wound healing, aid re-absorption of hematoma, reduce swelling, and reduce scar tissue. It increases blood flow in the area treated and increases cell membrane permeability to ions and other substances. It blocks signal transmission in nerves and decreases muscle spasms. It has been shown in clinical and scientific trials to increase collagen extensibility, enhance collagen remodeling, enhance collagen production, increase heat in deep tissues, increase blood flow, increase range of motion, reduce pain and muscle spasm, and accelerate wound healing.

Therapeutic effects of ultrasound are both thermal and nonthermal. Thermal effects are achieved by heating tissue using continuous-wave ultrasound. Thermal effects result from energy carried by ultrasonic waves being attenuated and absorbed by tissue as the waves pass through it. Some of the positive effects of heat produced by therapeutic ultrasound include improved extensibility of collagen, decreased pain, decreased muscle spasms, and increased blood flow. Nonthermal effects result from mechanical alteration of the local, cellular environment induced by the ultrasound waves. To avoid heating the treated tissue and achieve nonthermal effects, pulsed ultrasound is used where pulse rates interrupt the sound waves at rates of 50, 80, or 90%. Changes in cellular environment may lead to modifications in cellular function resulting in a shorter inflammatory phase of healing, increased vascularity at the treatment site, and enhanced proliferation of fibroblasts. Nonthermal ultrasound has been used as an adjunct therapy for patients with a fracture or a tendinopathy.

The temperature needed to achieve the desired therapeutic effect for thermal ultrasound has been established in humans. An increase of 1°C is required to increase the metabolic rate of tissue, an increase of 2–4°C is required to decrease pain, muscle spasms, and inflammation, and improve blood flow, and an increase ≥3°C is required to decrease the viscoelastic properties of collagen. For people, 1-MHz ultrasound is most effective at increasing temperature at a depth of 2.5–5 cm, and 3.3-MHz ultrasound is most effective at increasing temperature at a depth of 1.0–2.5 cm. Results of a study performed to evaluate the effects of 3.3-MHz ultrasound on the temperature of the thigh musculature of dogs showed that using a 10-minute treatment at an intensity of 1.0 W/cm² increases the temperature of tissue by 2–4°C at depths of 1.0 and 2.0 cm. At an intensity of 1.5 W/cm², the temperature of tissue increases by at least 2–4°C at depths of 1.0, 2.0, and 3.0 cm.

Research into the use of therapeutic ultrasound is lacking in the horse. Montgomery et al found that the superficial digital flexor tendon (SDFT) and DDFT are heated to a therapeutic temperature using a frequency of 3.3 MHz and intensity of 1.0 W/cm². However, the epaxial muscles are not heated to a therapeutic temperature using a frequency of 3.3 MHz and an intensity of 1.5 W/cm². Reis et al, using a frequency of 1 MHz on pulsed mode, at an intensity of 0.5 W/cm² for 5 minutes, treated collagenase-induced superficial flexor tendon lesions for 60 days. They found no significant difference clinically between treated and untreated limbs at either 15 or 60 days. However, there was a significant improvement in ultrasonographic evaluation at 60 days in treated limbs vs untreated. Singh et al evaluated the use of ultrasound for 10 minutes per day at 1 W/cm² for 6 days after induction of arthritis in donkeys. They found that gross changes in the joint capsule, synovial membrane, and articular cartilage were mild in ultrasound-treated donkeys compared with untreated controls.

In the author’s practice, therapeutic ultrasound is most commonly used for its heating effect on tendons and ligaments prior to exercise or mobilizations. We use 3.3 MHz and intensity of 1.0 W/cm²

11. Therapeutic Exercise
The amount and intensity of therapeutic exercise is dependent upon the condition being treated, the extent of the damage, the time of healing, and facilities available. Types include hand walking, riding, poinning (leading a horse while riding another), mechanical walker, underwater treadmill, swimming pool, and turnout to paddock or pasture. Each program is tailored to the individual and may need to be adapted during the rehabilitation program. Also, ground obstacles (ground poles, cavalettis) may be incorporated to increase coordination and agility. In addition, changing the terrain may be included to target specific areas (i.e., inclines to strengthen rear limbs). The goal of therapeutic exercise is to provide a gradual return to function and to improve strength and coordination.

Ground Exercises
Ground exercises are exercises that are performed at hand or while being ridden. They are usually targeted at specific areas such as improvement in proprioception and coordination, strengthening of
specific muscles, improving joint mobility, and improving overall body condition. There are many types of exercises that may be used. It is often based on the imagination of the therapist to develop specific exercises. One must take into account the nature of the patient and injury, the equipment and facilities available, and the personnel. Many of the therapeutic exercises are inexpensive and just require time and personnel. The following paragraph illustrates some different methods.

Proprioception and coordination may be improved by walking over ground poles placed in random fashion. Other configurations can be utilized. Different surface transitions may also be utilized such as going from grass to sand to gravel to water and then to asphalt. Different obstacles and pedestals can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized. Improving joint mobility can be accomplished by having cavallettis arranged like spokes on a wagon wheel and having the horse step over them going in both directions. Placing bracelets or weights around the pasterns can also be utilized.

Core muscle stability can be improved utilizing therapeutic bands placed around the caudal limbs or abdomen. Theses may be used at hand, lunging, or while being ridden. Strengthening of rear limb musculature may be accomplished by riding up and down gradual inclines or pulling a cart. This most commonly has been used as a therapy for intermittent upward fixation of the patella.

Equine Aquatic Therapy

Equine aquatic therapy primarily encompasses swimming and underwater treadmill. Whirlpools, salt water spas, and recovery pools are also examples but will not be addressed in this paper. Equine swimming pools have been available for 25–30 years; however, prior to that oftentimes ponds, lakes, or the ocean have been used. Many of the pools are located at tracks or barns. A few veterinary hospitals and equine rehab centers also have these pools. The main drawback is the expense on construction and the costs of maintenance.

More recently, equine underwater treadmills have been developed to overcome the expense of construction and maintenance of in ground pools. These units also provide a more controlled environment than pools with a decreased possibility of injury.

Swimming and underwater treadmill may provide several benefits. They primarily provide cardiovascular conditioning without the stresses on the musculoskeletal system. In addition, they provide a different type of muscle exercise and also work different groups of muscles than when working on land. Resistance to joint movement is also a benefit that is beneficial to rehabilitation.

The use of swimming and the underwater treadmill in the rehabilitation of musculoskeletal injuries is becoming more common. Their use allows the horse to maintain cardiovascular fitness, muscle tone, and improve joint movement without undue stresses on the injured limb. The reason for the decreased stresses placed on the limb is the buoyancy that the water provides. Depending on the height or depth of water, a certain amount of this depends on the amount of water in relation to the body mass of the horse. That is to say that a horse placed in a small area will require less water to get to the level of the point of the shoulder. Because of the reduced amount of water there is less buoyancy; thus, more weight being born.

Buoyancy is the force experienced as an upthrust, which acts in the opposite direction to the force of gravity. A body immersed in the water seems to lose weight, and the weight loss is equal to the weight of water displaced. Immersion in water allows for unweighting of tendons, ligaments, bones, and joints within the distal limb. There is a reduction ground reaction force leading to reduced concussive stresses on joints and tendons, allowing for exercise without further trauma induced by weight bearing or concussive forces. Reduced body weight decreases postoperative and convalescent complications. McClintock et al determined the weight reduction for a horse in a flotation tank filled with salt water. They found approximately a 10% reduction in the weight born by the limbs when the saline was at the level of the olecranon. When the saline was raised to the level of the tuber coxae there was approximately a 75% reduction in weight.

Immersion causes water displacement and increased hydrostatic pressure. Hydrostatic pressure is the sum pressure exerted on all surfaces of a body immersed in water, for any given depth. In humans this can cause redistribution of blood flow from the peripheral limbs due to an isotonic fluid shift from extravascular space. It can also lead to a decrease in hemoglobin and hematocrit levels within 25–60 minutes of water immersion. Hydrostatic pressure will affect lung volumes, hence care must be taken with patients with respiratory distress or compromise.

Viscosity is the resistance of a fluid to motion. Viscosity of water increases as speed increases. This is due to increased turbulence and drag. This in turn increases the amount and intensity of work being performed. The addition of hydrojets to the pool or treadmill can increase the drag on limb movement. Viscosity decreases as water temperature increases. This means weaker and smaller muscles move more easily in warmer water.

Relative density and specific gravity of an object will depend on the composition of the object and will determine whether an object will float or sink. So, lean animals and heavily muscled animals have a tendency to sink and animals with a greater amount of body fat will float more easily.

Both swimming and underwater treadmill exercise are forms of aerobic exercise and help develop cardiovascular fitness. With water immersion, there is a decrease in systemic vascular resistance.
and the changes in total peripheral resistance are dependent on water temperature.\textsuperscript{48}

Following underwater treadmill exercise, there is a moderate but not significant increase in blood lactate and plasma creatine phosphokinase levels.\textsuperscript{49} Hemoglobin concentration is significantly increased as a result of the physical exercise.\textsuperscript{50} Voss et al\textsuperscript{50} concluded that underwater treadmill training, following their training protocol, represents a medium-sized aerobic work load for horses.

Swimming causes a significant increase in blood pressure.\textsuperscript{51} However, the maximum heart rate obtained while swimming is less than that obtained during ground exercise.\textsuperscript{51,52} There seems to be no relationship between heart rate and duration of swimming.\textsuperscript{52} There also seem to be increased cardiovascular benefits while working at slower speeds.\textsuperscript{52,53}

Water pressure on the horse’s body during swimming prevents adequate ventilation.\textsuperscript{53–55} Hobo et al\textsuperscript{53} found an increase in respiratory rate, an increase in both inspiratory and expiratory pressure and that the expiratory time roughly doubled the inspiratory time. This suggested that a longer expiratory time may limit sudden collapse of airways by water pressure during swimming and prevent a marked decrease in air space volume and thus maintains buoyancy.\textsuperscript{53} There are no studies available on the effects of underwater treadmill exercise on the respiratory function in horses.

Walking in water at the level of the carpus or ulna resulted in a lower stride frequency and greater stride length compared with walking in water at hoof height.\textsuperscript{56} Water provides a resistance to movement of the limb in the sagittal plane; so an increase in height of the flight arc may also minimize the resistance experienced in swinging the limb back and forth.\textsuperscript{56} When moving in water between carpal and ulna heights, the horse may find it easier to adopt a rounder flight arc by increasing flexion of the hip, stifle, and hock joints. Water treadmill exercise may increase activity of muscles that flex the hip, flex the stifle, and protract the hindlimb.\textsuperscript{56} Borgia et al\textsuperscript{57} found no effect of water treadmill training on the properties of the gluteal and SDF muscles and on cardiocirculatory response to a standardized exercise test. However, the author’s state that a more strenuous water treadmill conditioning protocol may be needed to induce a training effect in gluteal and SDF muscle and heart rate response.\textsuperscript{57} Firshman et al\textsuperscript{58} found that 8 weeks of conventional or underwater treadmill training resulted in minor changes in type I muscle fiber sizes with no effect on muscle metabolic or heart rate responses to standard exercise test. They recommended that after rehabilitation involving underwater treadmills, training at progressing speeds is recommended for horses to develop the required fitness for speed work.

Evaluating the effects of swimming on 2-year-old Thoroughbreds in race training, Misumi et al\textsuperscript{59} found that fast-twitch, high-oxidative fibers increased. There was an increase in aerobic capacity of muscles and a decrease in fast-twitch, low-oxidative fibers. There was no change in slow-twitch fibers. They suggested that a training program including swimming training is seen as being useful for improvement in performance capacity, given that it can reduce locomotor diseases in young horses and allow for slow progress in future training.\textsuperscript{59}

Horses use their forelimbs to regulate their lateral balance and their rear limbs function in propulsion.\textsuperscript{52} The propulsive action of the rear limbs is exaggerated. During swimming, the equine back is lordotic. Because of the exaggerated rear-limb action and lordotic back, horses with rear-limb injuries or back pain should not swim. Nankervis et al\textsuperscript{60} also found that walking in high water causes cranial thoracic extension and thoracolumbar flexion compared with walking in water at hoof depth. They concluded that this postural change should be considered when designing rehabilitation programs for horses with back and/or hindlimb pathology.

There is an increased range of joint motion in both fore and hind limbs depending on water height. Joint angle in horses decreases as water approaches the carpus or hock, indicating increased flexion of the joints.\textsuperscript{61} Once the level of the carpus or hock is reached, joint flexion and limb height tend to level out. This may be used to target specific joints and aid in re-establishment of joint range of motion after joint surgery.\textsuperscript{61} However, if maximal flexion of a joint is desired, then water level should be carpal/tarsal level or higher.

Water density is 12 times greater than air.\textsuperscript{45} During aquatic therapy there is increased resistance to limb or body movement and increased energy costs compared with walking at similar speeds on land due to this increased density. This provides better muscle development and muscle tone due to working against resistance and provides better balance of muscle groups working against increased resistance while maintaining a symmetric gait.\textsuperscript{62} Underwater treadmill exercise significantly improves the horses’ postural stability.\textsuperscript{63}

Safety is important when swimming or using an underwater treadmill. It is very important that the handlers be thoroughly familiar with the equipment and must be able to read the horse’s temperament. The handler should be able to anticipate and correct problems with the horse or equipment before they develop.

Swimming pools should be constructed so that two handlers can easily walk 360° around. Water should be deep enough so that the horse cannot touch the bottom. A ramp entry system should be employed that allows easy entry and exit from the pool. Sides should be sloped to prevent injury. The water becomes contaminated with dirt and feces so a good filtration system is a necessity. Most horses are good swimmers but do require training. An introductory period is required with increasing
time intervals in the pool. Time is slowly increased to a period of approximately 15 minutes. There has been a protocol described using a swimming test to determine the level of fitness a horse has achieved following conventional training. However, it is not very applicable for determining swimming protocols.

There are two types of underwater treadmills: in ground and above ground. The in-ground type allows for a greater amount of water to be used thus there is greater buoyancy and greater resistance to movement. Both are variable speeds that range 0–15 mph. This is much lower than the high-speed treadmill, which is capable of achieving speeds of 45–50 mph. Horses require training on this equipment also. Both units require filtration and most have the ability to provide heated and unheated water.

Acclimation to water treadmill exercise requires a minimum of 2 × 15-minute nonsedated acclimating runs. Sedation can be used to prevent horses panicking during the first exposure but, thereafter, does not affect the time taken to acclimate.

Water temperature should be adjusted to provide maximized comfort. For active exercise and swimming use 65–82°F. For less vigorous exercise 96–104°F is acceptable. The least-adverse physiologic effects occur at 97°F. We keep our underwater treadmill at a constant 82°F.

Most facilities do not monitor any parameters either during or after a session, therefore, these recommended protocols are empirical. Two easy parameters that can be measured include heart rate and blood lactate levels. Heart rate can be used to monitor the levels of stress that are being placed on the cardiovascular system. Maximum heart rate in the horse is approximately 200 bpm. By using a heart rate monitor you can set a target rate and then set a time to stay in the target range. Blood lactate is used to determine whether the horse has progressed into the aerobic metabolism stage. This is a desired state to achieve adequate conditioning. Respiratory rate can also be used but is not as reliable as heart rate. In addition, lameness evaluation should be performed at weekly intervals to determine whether any musculoskeletal problem has arisen.

Indications for aquatic therapy include rehabilitation after injury or surgery, tendon injuries, postarthroscopic surgery, replacement for hand walking, joint stiffness, osteoarthritis, increase in muscle development, encouraging symmetric gait and back development, cardiovascular conditioning, and reconditioning after a lay-up.

Contraindications for aquatic therapy include acute joint inflammation, skin infections, open wounds, upper limb lameness (swimming), back pain (swimming), acute myositis, cardiovascular compromise, and respiratory disease.

The following are variables that must be considered when developing a protocol for an individual patient. Of utmost importance is the disposition of the horse. There are going to be some horses that may never acclimate to aquatic therapy. In these individuals another therapeutic plan will need to be developed.

- Injury and condition of patient
- Water level (if possible)
- Amount of buoyancy and limb weight bearing
- Degree of joint flexion desired
- Water temperature
- Warm vs cold
- Treadmill speed

<table>
<thead>
<tr>
<th>Table 1. Sample for an In-Ground Underwater Treadmill Program</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acclimation Period (D 1 and 2)</strong></td>
</tr>
<tr>
<td>Walk in and walk out of underwater treadmill</td>
</tr>
<tr>
<td>Turn on treadmill for short period if horse is comfortable</td>
</tr>
<tr>
<td>May use sedation during acclimation if needed. It also helps</td>
</tr>
<tr>
<td>to have a trained horse at the facility to act as a lead horse</td>
</tr>
<tr>
<td><strong>Rehabilitation program, days 3–7</strong></td>
</tr>
<tr>
<td>Speed-walk at 2 mph</td>
</tr>
<tr>
<td>Warm up, 5 min at 2 mph</td>
</tr>
<tr>
<td>Duration of active walk, 5 min at 2 mph</td>
</tr>
<tr>
<td>Cool down, 5 min at 2 mph</td>
</tr>
<tr>
<td>Frequency, once per day, 5 d per wk</td>
</tr>
<tr>
<td>Outcome measures</td>
</tr>
<tr>
<td>Walking comfortably for 5 min at 2 mph</td>
</tr>
<tr>
<td>If successful, proceed to next level</td>
</tr>
<tr>
<td><strong>Rehabilitation program, wk 2</strong></td>
</tr>
<tr>
<td>Warm up, 5 min at 2 mph</td>
</tr>
<tr>
<td>Duration of active walk, 10 min at 3 mph</td>
</tr>
<tr>
<td>Cool down, 5 min at 2 mph</td>
</tr>
<tr>
<td>May increase speed to 2–3 mph</td>
</tr>
<tr>
<td>Frequency, once per day, 5 d per wk</td>
</tr>
<tr>
<td>Outcome measures</td>
</tr>
<tr>
<td>Walking comfortably for 10 min at 3 mph</td>
</tr>
<tr>
<td>If successful, proceed to next level</td>
</tr>
<tr>
<td><strong>Rehabilitation program, wk 3</strong></td>
</tr>
<tr>
<td>Warm up, 5 min at 2 mph</td>
</tr>
<tr>
<td>Duration of active walk, 15 min at 3 mph</td>
</tr>
<tr>
<td>Cool down, 5 min at 2 mph</td>
</tr>
<tr>
<td>Frequency, once per day, 5 d per wk</td>
</tr>
<tr>
<td>Outcome measures</td>
</tr>
<tr>
<td>Walking comfortably for 15 min at 3 mph</td>
</tr>
<tr>
<td>If successful, proceed to next level</td>
</tr>
<tr>
<td><strong>Rehabilitation program, wk 4</strong></td>
</tr>
<tr>
<td>Warm up, 5 min at 2 mph</td>
</tr>
<tr>
<td>Duration of active walk, 20 min at 3 mph</td>
</tr>
<tr>
<td>Cool down, 5 min at 2 mph</td>
</tr>
<tr>
<td>Frequency, once per day, 5 d per wk</td>
</tr>
<tr>
<td>Outcome measures</td>
</tr>
<tr>
<td>Walking comfortably for 20 min at 3 mph</td>
</tr>
<tr>
<td>If successful, proceed to next level</td>
</tr>
<tr>
<td><strong>Rehabilitation program, wk 5</strong></td>
</tr>
<tr>
<td>Warm up, 5 min at 2 mph</td>
</tr>
<tr>
<td>Maximum exercise intensity, 4 mph for 30 min</td>
</tr>
<tr>
<td>Cool down, 5 min at 2 mph</td>
</tr>
<tr>
<td>May introduce cross-training activities</td>
</tr>
<tr>
<td>Frequency, once per day, 3–5 d per wk;</td>
</tr>
<tr>
<td>Outcome measures</td>
</tr>
<tr>
<td>Walking comfortably for at least 20 min at 4 mph</td>
</tr>
</tbody>
</table>
Hydrojets: On or off (if equipped)
Warm-up period
Duration of exercise: 5–30 minutes
Exertion during exercise
Frequency of exercise
Cool-down period

Table 1 is a sample program using an in-ground underwater treadmill. When using an in-ground unit there are only two variables that can be adjusted easily. They are speed and resistance. When using an above-ground underwater treadmill, an additional variable would be water height. It is also important to note that the speeds listed are relative. Speed will vary from treadmill to treadmill and may not be indicative of actual ground speed. They are used in the sample to show that speed should be gradually increased from a slow walk up to a fast walk or trot.

12. Return to Work
At some point the rehabilitation program will end and the horse must be returned to work if possible. It is important that return to work be performed gradually. Although the particular injury may have healed, the rest of the body may not be in condition. Table 1 is an example of a conservative back-to-work plan. We always recommend at least a 10-minute warm-up and cool-down period. It is important to determine whether the injury has healed sufficiently to allow for increased stress prior to progressing.

In summary, there are many different options for treating reduced range of motion or for maintaining normal joint motion after injury or surgery. The therapeutic protocols should be tailored to the individual. Response to therapy must be evaluated at different times during therapy to determine progress and whether a change in treatment is needed.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References


Practical Approach to the Rehabilitation of Soft Tissue Injuries in Sport Horses

Alan Manning, MSC, DVM

1. Introduction

Due to the nature of the sport, soft-tissue injuries are inevitable. Injuries can be the result of poor conformation, the level of training and fitness needed for the sport, and footing and weather-associated issues with the field of play.

Age-associated injuries occur as a result of the wear and tear associated with the chronic repetitive nature of sport, especially dressage horses. Sometimes it is just bad luck. There are many different ways to treat soft-tissue injuries, including platelet rich plasma (PRP), stem cells, IRAP, shockwave, laser, and ultrasound therapy. All have their pros and cons and the best mode of treatment must be decided for each individual case. Different veterinarians will have different approaches to each type of injury.

Once the initial treatments have been carried out and the clinician believes the horse is ready, the most critical part of the puzzle is getting the horse moving is important to help prevent scar tissue and promote the elasticity of tendons and ligaments, and to help prevent other secondary issues that arise from stall rest such as gastrointestinal (GI) issues, etc.

2. Handwalking

Handwalking is not always that simple. Horses on stall rest can be quite explosive at times. Walking
with a bridle on or a chain over the nose or in the mouth can definitely be helpful. Sedation is sometimes required. It takes a person with a lot of patience and good horse handling for this to be successful. The footing is also important. It requires good, consistent footing. Footing that is too deep can add stress to the injury. Sometimes it is safer and more prudent to walk the horse under tack depending on the case and individual horse. In a clinic situation or rehabilitation facility it is difficult to exercise more than one horse at a time, given that if one horse acts up, in most situations it will set off the other horses. Initially start at 10 minutes a day and increase walking to 20–30 minutes, one to two times a day depending on the individual case and injury severity. It is important to add in daily ice treatment following exercise to help decrease inflammation.

3. Starting to Walk Under Tack

Depending on the case but usually the sooner you can get started the better, and it is sometimes safer than walking in hand. Draw lines and sedation are sometimes required. There should be no lateral work, especially with suspensory ligament injury at first. When ready to add stress to the injury you can start to do some collected work and extended stride walking. It can also be done by walking over poles on the ground. You can then add raising the poles off the ground as well when ready. The next step would be walking up and down gradual hills if available to increase stress and stretching on the tendon/ligament.

Other modalities, such as treadmills, work well in certain situations. There is the cost factor (rent) to consider, but it does help save time, the horse walks at a consistent speed, the footing surface is consistent and the incline can be added when ready. You must be careful if the horse is not trained to use the treadmill before the injury, given that they have a chance of injuring themselves and/or re-injury when getting acclimatized to the treadmill (take time to train them to it). There is some concern of the constant concussion when walking on the treadmill.

Walkers are another option. They are time saving, decrease labor, and you can do more than one horse at a time. Concerns are the need for good footing in the walker, and it needs to be maintained. Walkers are not recommended for collateral coffin joint injuries due to the constant turning force on the front feet. There is also risk of re-injury due to the fact they can jump around, not as constricted as treadmill. The author usually does not recommend the walker until further on in the rehabilitation process, obviously the larger circumference of the walker the better (less stress).

The underwater treadmill can also be used to help increase cardio and muscle fitness, as well as add gradual stress to injury; the problem is they are expensive and horses must be trained to use them. They are time consuming to use and require maintenance, and there is risk of injury if the horse has not used it prior to initial injury.

A vibration plate is a good additional tool to the rehabilitation protocol. It allows increased muscle, tendon, and ligament fitness without adding additional stress to the injury, and also increases circulation to the lower extremities. The odd horse does not tolerate the time on it very well.

4. Support Bandage

Quite often the question arises: Should you use support boots or bandages during the rehabilitation process? Polo wraps do add some protection, but not a lot of support. Run-down bandages do add some support so do the Professional Choice boots. If these are used, the author likes to wean the horses off them during the rehabilitation process and just use protective sport boots.

5. Tentative Rehabilitation Schedule

When the horse is ready to start back into work, this could be anywhere on average from 3–6 months after the injury all depending on the severity of the injury.

First Month Back to Work

Walking under tack, 20–30 minutes per week and increasing by 5 minutes per week, up to 40–45 minutes at the end of the month. After 2 weeks start to walk over poles, and at 3 weeks start to do some gradual hill work. This could be split into two sessions in 1 day. Routine ice treatment following each exercise is always recommended. A phone timer works well to keep track of time.

Second Month Back to Work

Continue with walking regimen and start to trot 5–10 minutes, split each direction, and increasing by 5 minutes per week. Do not go deep into corners and no tight circles or lateral work initially. Near the end of the month you can start to trot trails and small gradual hills. The walking should be split before and after trotting, and the walking time will start to decrease as the trotting time increases.

Third Month Back to Work

Continue walk and trot, start some trot circles at 20 meters and raised trot poles and start canter work. Canter work can be done by time or number of rounds of the exercise arena, whichever is easier to keep track of. Start gradual and increase accordingly. No tight circles at the canter initially. After cantering for 1 month the horse can usually go back to full work and start to jump or begin more advanced dressage work.

6. Follow-up

It is very important to reassess the injury with a lameness examination and ultrasounds at regular intervals, every 4–6 weeks, and to make sure the
increased stress on the area has not had a negative effect on the healing process and the fiber pattern is improving. The rehabilitation protocol may need to be adjusted depending on the findings. The author finds that it is beneficial to do these evaluations before the horse steps up to the next level of rehabilitation, i.e., before trot, and again before canter.

7. Turnout
The other critical decision is when to start turnout. Once again, it is case- and individual-horse dependent. Small rehabilitation paddocks and small round pens are a great asset. Round pens can sometimes be increased in size as time goes. Some horses may need to be sedated at first. Feeding hay at turnout helps to keep horses occupied as well. The author feels at the earliest, turnout is appropriate 3 months following the injury but in some cases not until the horse starts cantering. The footing is very important and should not be too deep. Stone dust works well. Small outdoor paddocks (12 x 12 ft) with rubber mats are good initially and can be used much sooner after injury.

When the horse is ready to start jumping, usually after cantering for a month or more, and has been walking and trotting over poles on the ground and raised, the author usually recommends grid work. Trot into it and ensure that there is normal distance set for the individual horse’s stride. Obviously, start small and increase the size over time. (There is less stress on the injury in a horse at a normal takeoff distance and this is more likely to occur in a trot-in grid). Once the horse has been working in a grid for 2–3 weeks, you can start to use individual fences.

For the dressage horse, once he is ready you can start to do lateral work and more collected work. Obviously, the more advanced movements such as passage, piaffe, and pirouette are more stressful on different parts of the horse’s body and need to be added into work accordingly.

When soft tissue is healing, the new tissue needs to be educated on its job. This occurs during the rehabilitation process and has to be done gradually. Be careful not to overdo this during the rehabilitation process and cause re-injury. During the rehabilitation process, the elasticity and strength of the neighboring tissue above and below the injury needs to be increased. Also, given that the new tissue does not seem to have the same elastic properties as the original tissue, the author believes that the overall process of getting a soft-tissue injury back to competition successfully involves 25% treatment and 75% rehabilitation process. You cannot leave the client on their own to rehabilitate.

When a horse gets reinjured during the rehabilitation process it can be very frustrating. Depending on the degree of injury, sometimes the rehabilitation process must be backed up. If the injury is significant, have a discussion with the owner and/or trainer to decide whether the horse needs a new occupation that is less stressful. Sometimes when the horse reinjures, it is best to just do long-term paddock turnout for 6–12 months and reassess.

8. Points to Take Home for Successful Rehabilitation

- Need an accurate diagnosis
- Have a clear, concise written treatment and rehabilitation protocol (tentative) for the owner/trainer/groom
- Every case is different: approach it that way
- Do not need all the fancy rehabilitation equipment to do a good job and be successful
- Ice is your friend
- Walking under tack is very beneficial initially
- Regular evaluations of the injury and its progress are essential for success

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Author declares no conflicts of interest.
Muscle Injury Detection and Therapies

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Muscle injuries occur in horses to various degrees. The injuries can cause anything from poor performance to lameness. However, diagnosis may be difficult as the pain may only manifest itself during performance and may not be palpable. Infrared thermal imaging can be useful to determine the region of injury. Rehabilitation is based on healing, improving flexibility and muscle condition, strengthening the injured muscle, and then slowly returning to full activity. Author's address: Turner Equine Sports Medicine and Surgery, 10777 110th Street N, Stillwater, MN 55082; e-mail: turner@turnerequinesportsmed.com. © 2016 AAEP.

1. Introduction
Muscle pain and injury as a cause of lameness and poor performance in the horse is poorly recognized. In human athletes, muscle fatigue, muscle stiffness, muscle soreness, and muscle tears are well recognized and considered among the most common athletic injuries. In horses, muscle injuries are uncommonly documented as a cause of lameness. Fibrotic myopathy, stringhalt, and ruptured peroneus tertius are among the only muscle injuries reported in the horse.1 These lamenesses are usually characterized by the resultant gait abnormalities. Other muscle problems such as stress tetany, synchronous diaphragmatic flutter, exhaustion, post-exercise fatigue, tying-up (exertional rhabdomyolysis), and azoturia are regarded as specific physiologic disturbances.2 Muscle injuries frequently cause lameness in human athletes and racing greyhounds. Similar injuries therefore would be expected in the horse.

Factors that predispose to muscle strains include cold temperatures or impaired circulation to the muscle, local or generalized muscle fatigue, poor or insufficient training, and insufficient warmup.1 Cold has been shown to increase muscle tension and cause circulatory disturbances. This phenomenon causes earlier muscle fatigue, which can lead to uncoordinated muscle movement and strain. Fatigue predisposes to injury in two ways. First, muscle fatigue is a manifestation of general fatigue, which affects those groups that are maximally loaded. As muscles fatigue, they decrease in performance and elasticity, thus enhancing the likelihood of strain. Further general fatigue results in central nervous system incoordination of movement and predisposition to strain. Therefore, training must be designed to progressively increase the workload to develop the muscle groups, and to decrease early fatigue and permit rapid restoration of muscle function after exertion. Insufficient warm-up of muscles prior to exercise results in decreased circulation and lowered capacity to eliminate muscle waste products. Both these factors decrease the muscles' ability to sustain maximal performance.

The equine athlete is exposed to these predisposing factors on a routine basis. Hypothetically, if the horse suffers muscle strains, these injuries would most likely be manifested as lameness. The difficulty for the veterinarian is the positive diagno-
sis of these injuries. In human medicine, the athlete's description of the pain location is often the single most important factor in diagnosis. This diagnostic aid is obviously lacking in veterinary medicine. Many of these cases probably go undiagnosed in equine medicine because they cannot be confirmed by commonly used diagnostic methods such as radiographs and nerve blocks. As such, these lamenesses are most likely treated empirically with various combinations of rest, analgesics, and anti-inflammatory agents.

Some veterinarians have recognized muscle injury as a cause of poor performance. Sites in the forelimb include the biceps brachii, brachiocephalicus, the pectorals, and the musculotendinous junction of the superficial digital flexor. In the hindlimb, the semimembranosus and semitendinosus, adductor, gracilus, gluteal, and gastrocnemius muscle. Muscle tension, spasms, and pain have been recognized in the thoracolumbar region. In fact, localized muscle soreness is readily induced by a poorly fitting saddle or poorly balanced rider.

2. Diagnosis

As previously stated, the diagnosis of muscle injury in horses can be difficult. It is important to determine whether there was a history of a fall or other trauma, the duration of clinical signs, the presence of swelling, and whether lameness or poor performance has been documented.

The detection of muscle swelling or muscle loss as a result of fibrosis, chronic injury, or atrophy can be problematic. The horse should stand square, bearing weight evenly on all four limbs and with the head straight. The horse can then be assessed visually and the muscles palpated looking for fibrosis, tension or spasms, defects, or pain. Acute muscle tears may not be palpable because the defects become filled with hemorrhage, inflammatory debris, exudate, and edema. However, careful palpation can detect most superficial muscle injuries but deeper muscle injury is more difficult to identify.

Serum muscle enzyme concentration assessment, while very useful in the diagnosis of systemic muscle disease such as rhabdomyolysis, is of limited use in the diagnosis of muscle soreness or muscle tears.

In humans, part of the assessment includes evaluation of joint range of motion associated with the involved muscle as well as strength assessment. There are no data available for horses but this author believes this would be valuable information, especially for the assessment of rehabilitation.

Ultrasoundography can be very valuable in the assessment of the injury site. The most difficult aspect in horses may be the detection of the injury. The author has found infrared thermal imaging to be valuable in locating the area of injury.

Thermography is the pictorial representation of the surface temperature of an object. It is a non-invasive technique that measures emitted heat. A medical thermogram represents the surface temperatures of skin making thermography useful for the detection of inflammation. Although thermographic images measure only skin temperature, they also reflect alterations in circulation of deeper tissues. This ability to noninvasively assess inflammatory change makes thermography an ideal imaging tool to aid in the diagnosis of certain lameness conditions in the horse.

Thermographic muscle lesions have been described in horses. These lesions were defined as those with a 1°C disparity in temperature greater than 25% of symmetrical body areas. These disparities could consist of an increase or a decrease in temperature. Increases in temperature were suggestive of vasodilation associated with inflammation, whereas decreases in temperature were indicative of chronic scarring and reduced circulation or local edema, swelling, and vascular stasis due to severe inflammation. On the basis of the thermographic and clinical findings, the horse’s injury could be further categorized as one of three types of muscle injury: cranial thigh, caudal thigh, and croup region. The cranial-thigh muscle injuries included injuries in which the thermographic abnormality was over the quadriceps musculature (Fig. 1); the caudal-thigh myopathy included those cases in which the primary thermographic abnormalities were located over the caudal thigh muscle (Figs. 2 and 3); and the croup myopathy (Fig. 4) included cases shown thermographically to have inflammation involving the caudal loin, sacroiliac region, and hip. Since that report, muscle injuries have been diagnosed thermographically in the foreleg as well but these have been limited to muscles of the shoulder region.

According to some manuscripts, once the area is located, ultrasonography was used to characterize the nature of the injury. In each case, ultrasonography of the region of the “hot spot” revealed disruption of normal muscle fibers and varying sizes of hypoechogeticity typical of hemorrhage. A second lesion noted sonographically was a hyperechogeticity thought to be early fibrosis and a disruption of normal muscle/tendon patterns with focal hypoecho-
genic areas suggesting tearing of the musculotendinous junction.\textsuperscript{1,4}

Another diagnostic technique that may be of use is muscle biopsy. One case was reported in which biopsy of the thermographic “hot spot” revealed fasciitis of the fascia surrounding the muscle.\textsuperscript{4}

3. Rehabilitation
In humans, the goal of rehabilitating muscle injuries is based on three goals: 1) improving flexibility and muscle condition, 2) strengthening, and 3) return to full activity.\textsuperscript{5} Improving flexibility and muscle condition can be performed using a number of different techniques. Stretching exercises may be done from day 1 as long as they can be done without pain. If pain is felt, stop and wait. Stretching should be done regularly, at least three times a day in the early stages of rehabilitation. Horses stretch best by walking in a long and low frame. Stretching can be performed before exercise, to help the muscles warm up, loosen up, and relax; movements should not be forced and methods limited to what is tolerated. Carrot stretches are an excellent method. Work is limited to what the horse can do without pain. Likewise, intensity is limited to the gaits the horse can perform without pain. But if the horse is capable, ground poles or cavalettis can stretch the horse as can bending exercises. After exercise, one can take advantage of warmed-up muscle and force the stretch more.

Sports massage techniques are exceptionally useful after the initial acute stage (usually 48 h).\textsuperscript{5} This will relax the muscle, loosen and help prevent scar tissue formation, and encourage blood flow and healing of the muscle. Massage has many techniques, generally, massage movements should go with the lay of the hair (following the direction of the muscle fibers), sometimes transversely but never counter. Counter movements may induce muscle spasms.

Horses, because of their size, may be difficult to stretch or massage, that is where therapeutic devices have been helpful. Therapeutic sound and electrical stimulation are among the most common devices used. Therapeutic sound devices can be divided into therapeutic ultrasound and shockwave. Therapeutic ultrasound is a method of stimulating tissue beneath the skin’s surface using very high frequency sound waves, between 800,000 and 2,000,000 Hz, which cannot be heard by humans.\textsuperscript{6} Ultrasound is applied using a transducer or applicator that is in direct contact with the patient’s skin. Gel is used on all surfaces of the head to reduce friction and assist transmission of the ultrasonic waves. There are three primary benefits to ultrasound. The first is the speeding up of the healing process from the increase in blood flow in the treated area. The second is the decrease in pain from the reduction of swelling and edema. The third is the gentle massage of muscles, tendons, or ligaments in the treated area because no strain is added and any scar tissue is softened. These three benefits are achieved by two main effects of therapeutic ultrasound. The two types of effects are thermal and nonthermal effects. Thermal effects are due to the absorption of the sound waves. Nonthermal effects are from cavitation, microstreaming, and acoustic streaming.\textsuperscript{6} The thermal effects have been documented in horses, the nonthermal effects have not.\textsuperscript{7}

Extracorporeal shockwave therapy are abrupt, high-amplitude pulses of mechanical energy, similar
to soundwaves, generated by an electromagnetic coil or a spark in water. "Extracorporeal" means that the shockwaves are generated externally to the body and transmitted from a pad through the skin. With extracorporeal shockwave therapy, reduced pain, and faster healing are reported. The exact physiological mechanisms at this stage are poorly understood, but it seems that the cells undergo microtrauma, which promotes the inflammatory and catabolic processes that are associated with removing damaged matrix constituents and stimulates wound-healing mechanisms.9

Electrical stimulation or electrical muscle stimulation, also known as neuromuscular electrical stimulation, is the elicitation of muscle contraction using electric impulses. Electrical muscle stimulation has received increasing attention in the last few years because of its potential to serve as a strengthening tool for healthy subjects and athletes, a rehabilitation and preventive tool for partially or totally immobilized patients, a testing tool for evaluating the neural and/or muscular function in vivo, and a post-exercise recovery tool for athletes.9 The impulses are generated by a device and delivered through electrodes on the skin in direct proximity to the muscles to be stimulated. The impulses mimic the action potential coming from the central nervous system, causing the muscles to contract. The electrodes are generally pads that adhere to the skin. Electrical stimulation is reported to have many benefits: 1) pain relief caused by decreased spasticity of muscle, 2) improved range of motion caused by reduced muscle tension, 3) reduction in swellings caused by injury, 4) reduction of scar tissue during healing, 5) re-education of muscle function to prevent further injury, 6) strengthening of muscles and tendons, 7) reversal of muscle wasting, and 8) decreased rehabilitation time after injury and surgery.9

There are different types of electrical stimulation. Among the most common are transcutaneous electrical nerve stimulation (TENS), which is the use of electric current devices to assist with short-term or long-term pain relief.9 TENS units are designed to produce analgesia of pain and reduce responses of dorsal-horn neurons to painful stimuli. The TENS systems activate the descending inhibitory pathway from the brainstem to the spinal cord. However, the means of reducing pain varies between the specific types of systems and includes activating spinal cord gating mechanisms, endogenous opiates, serotonin receptors, noradrenaline receptors, and muscularic receptors. Regardless, the electrical signals cause muscles under the electrodes to contract.

Another type of electrical stimulation is functional electrical stimulation (FES).9 FES is the application of an electrical current through surface electrodes to produce a controlled muscular contraction. A microprocessor generates a train of impulses that imitate the neural signals that pass between the spinal cord and the peripheral nerves in healthy muscle, producing a muscle contraction. FES is utilized to disturb spastic hyperexcitability, returning the muscle to its balanced contraction and relaxation phases, therefore reducing pain. FES devices are designed to stimulate motor nerves but peripheral nerves are also stimulated when motor nerves are activated, so there is a combined effect. FES provides a means to mobilize muscle, tendon, and the associated ligaments through the generation of controlled muscular contractions. FES can be used for stimulation of deeper tissues; and therefore, the attainment of strong muscular contractions is possible. Stronger contractions have been shown to be more effective in reducing pain, and the benefits have proven to be longer lasting than other forms of electrical stimulation.

Pulsed electromagnetic field therapy is a reparative technique most commonly used in the field of orthopedics for the treatment of non-union fractures, failed fusions, congenital pseudarthrosis, and depression.10 More recently, pulsed electromagnetic field therapy has been used more for healing other types of connective tissue including muscle. Regardless of the modality, to achieve the goal of improving flexibility and muscle condition, it is the author's opinion that the horse must remain in at least low-intensity exercise.

Strengthening the muscles is important to avoid re-injuring the muscles. It is especially important to strengthen the muscles in the same direction/way that they were injured. Light strengthening exercises can begin after the acute stage or as soon as pain allows. If they are painful then stop and wait. Horses gain strength by flexion (ground poles and cavalettis), through transitions of gait, stress (deep footing, hill work, etc.) and lateral work (may be most difficult, especially for inner-thigh injuries). For humans, there are protocols for strengthening specific muscle groups, but these protocols do not exist for horses at this time. There is work ongoing using therapeutic banding, treadmills, and underwater treadmills, but the results are not complete. Most build strength through controlled exercise.

Strengthening exercises may be done on a daily basis in the early stages of rehabilitation and as intensity increases and full activity is regained they may be reduced to three times a week. Stretching exercises should be continued throughout the strengthening process both before and after a strengthening session.

The return to full activity should be a gradual process. Do not go straight back into regular work but build up gradually from slow trotting. When the horse can slow trot for 20 minutes without problems, gradually build up speed. Extended trot should lead to canter and canter to gallop, gradually increasing to what is needed for competition.

Only when the horse can comfortably manage specific training should they be returned to full training or competition. As training is commenced, massage therapy, acupuncture, and in some cases chiro-
practic adjustments can help the horse recover. But for the long term the author has found that altering the exercise program can be most beneficial and conditioning is of utmost importance. The work schedule should be a progressive schedule that will take 60–90 days, and ideal work schedule is 6 days per week. Initially, most exercise should be warmup (stretching). This will consist of walking in a long and low frame until the rider can feel the hips moving equally and a normal overstride behind. Once achieved, the horse should be worked over ground poles for 15–20 minutes. When ground poles become easy, change to cavalletti. Exercise for at least 1 hour. As work becomes easier then slow trot can be added. Work in a long and low frame (extended frame). This will help stretch the horse’s top line and any tight muscles there. Once the horse can slow trot consistently for 15 minutes, then the intensity (speed) can increase. When 15 minutes of extended trot is achieved, the canter can be added. Work the horse for at least an hour each day. Lateral work should not be added until the horse can consistently canter for 15 minutes without problems.

In addition, vigorous massage of the tight muscles in the horse’s back, croup, and thigh before and after exercising the horse may be helpful. Post-exercise body wash with liniments, intense massage, and therapeutic ultrasound treatments may be helpful in alleviating soreness. Attention to the horse’s trimming and shoeing should concentrate on hoof balance (especially rearlimb sole angle) and traction. During this retraining period, infrared thermal imaging can be used to assess muscle stress to insure that too much stress is not applied. Stress would be seen as abnormal heat in the skin overlying the muscle.

4. Discussion

The most common cause of muscle inflammation is muscle strain. A classification of first-, second-, or third-degree strain injuries, described in human athletes, has been applied to horses. In one study, areas of hindlimb muscle injuries in horses were identified. One, the croup myopathy, involved inflammation over the areas of the longissimus lumbarum muscle, gluteus medius muscle, gluteus profundus muscle, the sacroiliac joint, and the gluteal insertions on the greater trochanter and associated fascia. The analogous regions in man would constitute the lower back and hip. The second, the caudal thigh myopathy, involved the areas over the biceps femoris muscle, the semitendinosus muscle, the semimembranosus muscle, and their origins and their upper limb insertions and musculotendinous attachments. This would be analogous to a hamstring injury. The third, the cranial-thigh injury, constitutes damage to the quadriceps and tensor fascia lata.

A gluteal tendon lameness has been described in the horse; the major clinical sign was pain around the greater trochanter. There have been numerous reports of the effect of lumbar and sacroiliac pain leading to lameness. For the purposes of this paper, the author has chosen to place these rear end muscle issues into one of these three general categories because palpation and thermography cannot specifically identify the structures involved. Thermography only reflects problems of deeper tissues, (i.e., it suggests the area of disease but does not reveal any information as to the nature of the organic damage). The grouping of these problems together is because of their close anatomical location and similar effects on the horse’s gait.

Muscle injuries in the horse have been described as ranging from loss of performance to pain created by a particular movement to overt lameness. The wide range of degree of lameness reported in the horse supports this observation. In one report, the caudal thigh myopathy was more likely to cause severe lameness than the cranial thigh or croup muscle injuries. The caudal thigh muscles may be more likely to tear, and tears in this group of muscles have been documented. Fibrotic myopathy, a condition of the horse that involves the semitendinosus muscle and occasionally the semimembranosus and biceps femoris muscles, is thought to originate from trauma to the musculotendinous junction. Another possible reason for the greater pain associated with these injuries is the complex actions of these muscles. This group of muscles extends the hip, flexes the stifle, and extends the hock. Because of the action of the horse’s reciprocal apparatus, all three functions cannot occur simultaneously unless muscle contraction is coordinated. Hypothetically, if an injury occurred, the horse should have pain each time the leg was extended because stifle extension would exert a direct opposing force on the caudal thigh muscles as they contract for hip and hock extension. Forelimb muscle injuries occur but they have been poorly reported.

Pain on palpation is probably the single most important physical evidence of injury. Pain elicited by palpation should be repeatable, but care should be taken not to overdo palpation which may result in the horse “guarding” the injury and thus not responding. The author has found that firm pressure was more reliable than squeezing muscle masses when trying to differentiate pain from simple annoyance. Stress points have been described that help point to lesions of these muscles. Stress points are the points where the greatest stress produced by movement occurs. However, palpable pain is not reliable with regard to muscle strains and tears.

Thermography can be used in these cases as a diagnostic tool. In each case, information from thermography is important in determining the region of injury. Thermography has been shown to be a practical aid in the clinical evaluation of lameness. This modality specifically increases the accuracy of diagnosis by confirming inflammation in palpably sore areas and by showing the area to concentrate
further diagnostic testing such as sonography or muscle biopsy. Clinically, thermography also improves therapy. Once the area of inflammation is determined, physical therapy can be applied directly to that area. In this fashion, therapeutic ultrasound, massage, or other treatment is applied more specifically to the inflamed area. Further, thermography can be used to monitor the resolution of the inflammatory process and possible recurrence during the rehabilitation.

5. Conclusion
Muscle injuries occur in horses to various degrees. The injuries can cause anything from poor performance to lameness. However, diagnosis may be difficult as the pain may only manifest itself during performance and may not be palpable. Infra-red thermal imaging can be useful to determine the region of injury. Rehabilitation is based on healing, improving flexibility and muscle condition, strengthening the injured muscle, and then slowly returning to full activity.

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The Author declares no conflicts of interest.

References
Physical Therapy Approach to the Equine Athlete

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1. Horse and Rider Interplay
Equestrian sports are unique in that athletic performance is largely dependent upon the skill, ability, and integration between both horse and rider. Any deviation from normal anatomic or biomechanical function of either athlete may result in less-than-desired outcomes. Therefore, to maximize full potential of athletic performance, physical therapists and veterinarians who specialize in equine sports medicine must address pertinent musculoskeletal, neuromuscular, and biomechanical faults that might impede how the rider affects the horse and the horse affects the rider. The symbiotic relationship between horse and rider has become a topic of special interest in recent literature, and recognized as an important entity in need of more in-depth research.1–3

Experts in the field of equestrian sports have begun to identify a variety of dysfunctional and even pathologic conditions resulting from disharmony between horse and rider.2,6 For example, specific exercises designed for core stabilization and strengthening for both horses and riders have been shown to improve trunk balance, abdominal strength, proprioception, and pelvic symmetry, resulting in increased support of the spine and extremities during dynamic activities.7,8 In contrast, weak core muscles and lack of dynamic stability result in postural imbalances and abnormal biomechanics that may in turn lead to low back or hip pain in riders and lumbar or sacroiliac dysfunction in horses. Over time, imbalanced muscle strength and flexibility will lead to chronic conditions of decreased joint mobility, impaired active and passive range of motion in the spine and extremities, and ultimately, a decrease in sport performance. The following analogies will help clarify these points.

2. Symbiotic Relationship
In equestrian athletes, acute muscular back or pelvic pain left untreated will cause the rider to position himself unbalanced in the saddle.8 An unbalanced rider will subsequently create unequal seat pressures which, by nature of interplay, will directly transfer as uneven forces to the spine and rib cage of the horse.9 A rider that possesses uneven saddle pressures will result in a horse needing to compensate in response to the abnormal and often uncomfortable forces placed on its spine. If the rider’s positional faults are neglected for long periods of time anatomic adaptations in the horse will occur, leading to potential restrictions in costovertebral and zygapophyseal joint mobility, ultimately leading to decreased sport performance. Over time, a horse or rider that continues to perform without...
correcting muscle imbalances will be prone to acquiring acute or chronic injuries secondary to a cascade of compensatory mechanisms.

For example, a competitive showjumping horse experiencing pain in the lower spine may compensate during takeoff by overusing muscles in the hind limbs. Over a period of time, soft tissues subjected to overuse will eventually break down, leading to potentially debilitating muscle trigger points, tendinosis, or tendonitis, acute tearing of muscle and ligamentous tissues, and bony stress fractures. If injuries are severe enough, the equine athlete may be eliminated from competition for a period of time or indefinitely.

Another example illustrating the importance of correcting muscle and soft tissue imbalances to restore harmony between horse and rider may be taken from the equine perspective. Take a case where a competitive showjumping horse has developed degenerative changes in the fourth through seventh cervical vertebrae. The bony changes may or may not be painful to the horse, however, they will most likely have created decreased segmental mobility in the zygapophyseal joint capsules resulting in decreased cervical sidebending range of motion. The loss of cervical motion will affect the horse’s ability to turn either right or left when showing. This will subsequently alter the optimal dynamic balance between horse and rider and result in a decrease in performance. The rider may describe the problem as, “My horse does not turn to the right or left very well,” but in fact the horse has a very treatable condition from a physical therapy paradigm of clinical reasoning.

A physical therapist will clinically address soft tissue and joint restrictions in the equine cervical spine utilizing a similar line of clinical reasoning as applied to humans; by incorporating skilled manual therapy and adjunctive techniques to treat myofascial and connective tissue dysfunction and restore normal joint arthro and osteokinematics. In the case of degeneration in the cervical spine, a therapist will treat the equine client through use of manual therapy, aided by appropriate physical agents to address muscle spasms, trigger points, and soft tissue restrictions. Successful clinical outcomes will be assessed by increased passive and active cervical side-bending range of motion and improved sport performance. Rider feedback will indicate a noticeable increase in cervical spinal mobility in the horse during performance and a sense of greater efficiency with dynamic trunk balance in saddle while showing. Finally, another interesting phenomenon occurring in both humans and horses relates to how even minor physical ailments or lesions in joints or soft tissues, if left untreated, may negatively impact musculoskeletal mechanics and sport performance. For example, with human athletes, ligament sprains or tendon strains that fail to heal properly over time may result in compensatory biomechanical faults and joint hypomobility ultimately leading to a reduction in sport performance. A similar cascade of events occurs in horses that experience improperly healed injuries as described by the following example.

In an equine athlete, a low grade or sub-clinical case of soft tissue injury or dysfunction to either the superficial or deep digital flexor tendons in the hind limb may clinically manifest as compensatory biomechanical faults in proximal limb function, sacroiliac joint movement, and thoracolumbar segmental mobility. The secondary faults may in turn result in painful palpation to soft tissues, asymmetrical conformation in the extremities and spine, observable lameness that defies definitive diagnoses, and diminished sport performance. The focus of care for the equine client exhibiting compensatory biomechanical faults is to appropriately identify and treat both primary and secondary sources of injury and ultimately restore normal tissue function to prolong a successful athletic career. The fundamental goal for physical therapists and veterinarians practicing sports medicine is to maximize athletic potential and performance. This is accomplished by restoring and elevating the highest level of anatomic and biomechanical function physically capable from both horse and rider in addition to addressing overall body conditioning utilizing a holistic approach to care. In more severe cases of injury, however, either the rider or horse may require controlled rest from competition long enough to adequately rehabilitate injuries in need of greater periods of recovery.

3. Physical Rehabilitation

In situations in which an injury to an equine athletic may require temporary cessation from sport, the animal will benefit from a combination of both veterinary care and a period of skilled physical therapy intervention. The goals of therapy will be to eliminate signs and symptoms of pain and swelling, restore normal function of involved tissues, and properly recondition the involved athlete for a return to sport. In contrast, a complete lack of implementation or inadequately controlled rehabilitation may lead to a vicious cycle of repetitive injuries or chronic pain, which in turn may preclude an athlete from returning to sport altogether.

A complete cycle of injury and recovery will occur when damaged tissues are subjected to appropriate internal and external environments that support the healing process. To illustrate, assume a competitive equine athlete sustains an acute micro-tear of the deep digital flexor tendon on the hindlimb. A typical sequence of healing would include an inflammatory stage, followed by cellular proliferation, and finally remodeling and maturation of the tendon. Successful healing will occur if the cellular and microvascular environments remain healthy, and if the horse is properly cared for through use of active rest, proper nutrition, and therapeutically prescribed exercise to restore tissue homeostasis and enable successful return to sport.
If, however, the deep digital flexor tendon does not heal properly, or the horse returns to sport prior to complete maturation of tissues, then re-injury of the tendon will most likely occur, along with additional compensatory sequelae such as overactivation of the hamstrings or lumbar paraspinal muscles. If this reaction occurs, the horse may fall into a vicious cycle of pain, spasm, and dysfunction of involved tissues causing secondary lower back pain cascading into additional biomechanical faults in gait, and jumping ability. Intervention with this scenario by a qualified physical therapist, however, will help break the pain/spasm cycle and restore injured tissues back to a state of normal function.

The primary emphasis of a structured physical therapy plan of care for any condition is to restore normal anatomic, physiologic, and biomechanical function, and return the athlete to all desired activities, including sport performance. To accomplish these goals, a physical therapist will create an individualized treatment plan based on a thorough evaluation and selection of appropriate interventions. Interventions may include such things as specific manual therapy techniques to restore normal function in joint and soft tissues, physical agent modalities to support the healing process, and tailored therapeutic exercises to address muscle, cardiovascular, and respiratory conditioning. Failure to achieve these goals during rehabilitation will result in inadequately healed tissues, lack of proper conditioning, and ultimately reduced sport performance, or possibly a complete end to an athletic career.

4. Equine Performance Enhancement

One of the key elements for any athlete to perform at peak levels in sporting activities is to be in absolute top condition both physically and psychologically. These factors are the same for both human and equine competitors. In human medicine, a large body of research exists demonstrating the importance of proper physical conditioning and how various fitness parameters relate to sport performance.12–18 This is true for athletes competing in all sports that require strength, power, agility, aerobic, and anaerobic capacities. In the world of equine, the amount of research on athletic performance, especially related to sport specific demands, is significantly less than in human medicine. However, the equine athlete experiences many of the same physical challenges as human counterparts. For example, common issues encountered when working with elite performing horses include damage to ligamentous and muscle tissues; loss of or altered proprioception, vertebral hypo or hypermobility; decreased joint range of motion; loss of strength, decreased soft tissue flexibility; core weakness; asymmetries such as muscle imbalances in the pelvic, lumbar, and cervical regions; and overall aerobic and anaerobic deconditioning.19–22

A few experts have addressed some of the more common issues encountered in horse performance, but overall, the science of sports medicine specifically related to the equine athlete remains in its infancy in both scope and depth. Studies have been conducted on basic equine physiology with references to athletic performance, but data related to sport-specific demands has primarily centered on biomechanics, core strengthening exercises, foundational stretching techniques to enhance overall mobility, and parameters to improve speed and endurance. Studies that directly correlate how altering biophysical parameters in a horse specifically affect sport performance in relation to outcomes is significantly lacking. An even greater void of knowledge exists, however, regarding the best way to maximize training and conditioning programs for equine athletes based on sport-specific demands.

5. Equine Training and Conditioning

To address the topic of equine conditioning for sport performance, one of the authors of this paper distributed a survey to professional trainers involved with Grand Prix riders in the United States, many at the Olympic and World Cup level.23 A total of 50 professional trainers were asked a series of questions related to how they personally trained elite show-jumping horses in preparation for competitions. Several themes emerged from the questionnaire demonstrating both consistent and inconsistent findings. In general, trainers agreed on the following factors: the earliest age to start jumping a horse is 4 years; the average age to enter a horse into a Grand Prix event is 8–9 years; application of ice on the lower extremities post jumping; and attitudinal changes in horses do in fact occur with overtraining.

Items found to be inconsistent based on data from surveying trainers included the following: no agreement on weekly training schedules; a lack of specific exercises used for conditioning horses; no descriptions of generalized fitness programs to use year round; no agreement on standardized recovery periods post competition; a lack of sport-specific exercises related to aerobic/interval/gymnastic/speed work/roll backs or lateral training; and no standardization of the number of classes per week allowed for the horse nor the amount of jumps allowed when a horse is not competing. In addition, other findings from the survey data are worth noting.

Horse trainers expressed no knowledge of the science underlying formalized training programs, and the concept of periodization as a scientific way to condition a horse both on and off season was absent from all responses. The physiological basis of equine delayed-onset muscle soreness post-exercise was also never mentioned in the survey. Exercise recovery time and parameters indicating how trainers worked horses during nonjumping days during competition were other topics completely lacking from data analysis. Of interest, however, all of the principles just noted in relation to exercise physiol-
ogy and general conditioning programs for sports are routinely used on a scientific basis in human medicine, and have been for decades. Therefore, results from the trainer survey call to question why concepts that are so commonly understood and successfully used in training elite human athletes have not been formally researched and applied in elite equine athletes.

In conclusion, the overarching theme from the survey of 50 professional trainers regarding equine conditioning programs was the clear lack of consistency between training regimens and omission of understanding for basic physiological principles of fitness and conditioning. Although additional data are necessary to extrapolate statistical conclusions, themes from the current survey suggest a need for scientific evaluation of what constitutes best practice by way of fitness training and conditioning for the equine athlete.

6. Practical Applications

The quantity and quality of research supporting equine sports medicine in human athletes should and can be adapted and applied in similar fashion to the equine athlete. Basic principles and concepts of physical conditioning, fitness, and rehabilitation have already found success in canine sports medicine leaving no reason as to why they cannot be applied equally as well to the equine species. Physical therapists and veterinarians who specialize in exercise physiology, strength and conditioning, and enhancement of sport performance have the knowledge and skills to push the limits of equine sport performance to even greater heights than what currently exists today.

Research into evidence-based principles of exercise physiology including aerobic and anaerobic conditioning, muscle mutability, soft tissue extensibility, and advances in the science of physical and neurologic rehabilitation has created exciting opportunities for individuals involved in training and competing equine athletes. Although the future of equine sports medicine looks bright, clinical practice requires validation by scientific methods that support outcomes-based protocols for conditioning and training regimes both on and off season. Current experts in equine studies have produced an impressive body of knowledge related to exercise physiology and sport conditioning providing a solid foundation to aid future scholars and clinicians. If existing knowledge can be successfully integrated into new paradigms of scientific inquiry the outcome will result in a class of equine athletes with the capacity to exceed never-before-imagined accomplishments in physical performance.

7. Conclusion

The symbiotic interplay between horse and rider in all equine sports is paramount and must not be overlooked by experts in the field. Factors including physical fitness, aerobic and anaerobic conditioning, strength, flexibility, proprioception, and other complex biomechanical factors that affect the rider will also affect the horse, and visa versa. Both human and horse need to be conditioned and functioning at peak performance to truly display the full potential of athletic achievement in all equestrian sports, especially those requiring extreme tests of strength, power, endurance, and agility.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

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Taking the Lessons From Stall Side to the Classroom

Racquel M. Rodeheaver Lindroth, DVM, DABVP (Equine)

1. Introduction

As equine veterinary professionals, we are often called upon to be educators. Our clients look to us as partners who guide them on a regular basis to make informed decisions about the care of their equine companions. Our colleagues frequently seek our expertise, advice, and mentorship. Our communities respect us as resourceful leaders when it comes to concerns such as public health or animal welfare. We are well practiced at the art of informing. Making a career transition into the academic domain may provide a highly suitable fit for those who have talent and passion for teaching.

Dr. Dean Hendrickson, Professor of Surgery and former Director of the Colorado State University (CSU) Veterinary Teaching Hospital, acknowledged the value of experienced practitioners in the role of clinical teaching. He described the desired “hybrid” as an excellent clinician who is also an excellent educator and is most suitable for teaching in areas of primary care such as equine field service. Similarly, Dr. Bryan Slinker, Dean of the College of Veterinary Medicine at Washington State University, discussed a variety of roles intended for general practitioners who are recruited to teach veterinary students, especially in the areas of primary care. Washington State University has deliberately partnered with clinicians in the private industry to offer formal training programs for veterinary students.

In fact, experienced clinicians can offer advantageous teaching skills that complement those of specialists. Dr. Emma Read and Dr. Sarah Baillie recently considered the challenges faced by veterinary students as they learned a new skill or technique. They evaluated techniques used to effectively teach the skill and decision-making process for bovine dystocias, recognizing how the learning curve is even more complex for the student when the procedure is internal and unsighted as with...
obstetrics. “Learning is easier when detailed instructions are available, but experts often find it difficult to articulate all of the steps involved in a task or relate to the learner as a novice.” Bringing in veteran bovine practitioners who could provide relevant step-by-step instruction enhanced the overall teaching experience and improved performance outcomes for the students. In addition, as teaching protocols were established for this study, the different approaches between experts highlighted the need for consensus before teaching the skill.

Keep in mind that well-practiced generalists are valued experts. Dr. Stephen May brings to our attention that “a difficulty in understanding primary health care expertise arises from the way in which the term ‘expert’ and ‘specialist’ have become synonymous in the minds of many, with the implications that the generalist is not an expert.” He emphasizes the achievements of first opinion practice and those responsible for its delivery. From his viewpoint, formally integrating “expert generalists” into veterinary teaching programs should be strongly considered as we best prepare professionals for careers in primary health care.

Teaching both the art and the science of equine practice becomes relevant. Qualified practitioners bring forward supplementary experience and understanding in their teaching styles. Through the course of practice, reflective practitioners have likely accomplished important skills in critical analysis and evidence-based decision making. In addition, they offer remarkable guidance regarding client relations, communication skills, and business management.

Equine practitioners also play an essential role as ambassadors, building bridges between academic institutions and the equine industry. Dr. Jerry Black, founder of Pioneer Equine Hospital and present Director of Equine Sciences at CSU, commented that many organizations in the equine industry have provided tremendous contribution as educational partners by sponsoring programs, offering scholarships, and even creating internship opportunities for students. Equine practitioners have usually established trustworthy relations with industry partners through years dedicated to clinical practice and building successful businesses. This greatly enhances the overall network.

Pursuing an academic career path will be interest driven and custom designed for each individual. Whether you are a specialist who has always thrived within the academic domain or an experienced clinician returning after years in the field, keep in mind that each member plays a vital role in the education of young professionals.

2. Preparing the Pathway

Many of us as practitioners have crafted intentional teaching moments throughout our career pathway. We offer client seminars, presentations to the local 4H club, a guest appearance to our child’s kindergarten class, a written article for a horse owners’ publication, a continuing education seminar for our State Veterinary Medical Association, or a how-to paper at an American Association of Equine Practitioners Convention. The opportunities to develop your skills as an educator are plentiful and readily available. Many who formally transition into a career of education have built a track record of signing up for such education opportunities.

Identify your personal strengths and run with them. To successfully lead as an educator, you have to first believe that you will have a positive effect on others. You must have confidence that your words will inspire and your actions can move others. Believe wholeheartedly that what you teach will make a difference. Then the question becomes, “What difference do you want to make?” Identify your unique abilities and activities for which you have superior skill, passion, energy, and a never-ending desire to learn. Leverage what distinguishes you and share it with others.

Develop a forward-looking vision and chart the course. Once you have identified your desired niche for teaching, begin to describe the details that provide you with a sense of direction toward specific goals. This may represent the design of one presentation or could signify creating an entire curriculum. Create a course outline that clearly identifies the learning objectives. In effect, this provides clear definition of what the learner should be able to demonstrate or perform upon successful completion of their learning. Taylor emphasizes that “learning tasks and assessments that are constructively aligned to intended learning outcomes have a profound, positive effect on what and how students learn”. Know clearly where you want to go as you inspire and guide others who willingly join you on the educational journey.

3. Staying Relevant

Accomplishing a degree as Doctor of Veterinary Medicine through a rigorous 4-year professional program is only the beginning. Truly we are life-long learners, encouraged to stay current over 40 years of a career. To be capable and effective as clinicians we recognize the importance of continuing education. Similarly, success as an educator requires us to be competent and up to date in our field of expertise.

Sometimes it’s daunting to recognize the need to keep ourselves relevant. As we strive to keep learning, keep in mind that we cannot be expected to know it all. Technology, for example, has certainly become more advanced in the classroom. Technology has allowed us to expand our teaching methods with innovation and creativity but does require a skill set. Offering an online course presentation may be new in your teaching experience. But do not let technology inhibit you. Keep an open mind and learn how to adapt to new approaches.
For many of us, no one has taught us how to teach. If you desire to pursue the academic pathway, consider taking some courses in faculty development. There are notable affiliations that hold symposia distinctly for educators of the equine discipline in order to facilitate sharing of information and advance teaching methods. Staying relevant should also imply acquiring teaching skills to effectively create an active learning environment for our students.

Furthermore, consider another important dimension of competence as an educator. Being functionally competent in order to teach a skill or a concept is necessary but may be insufficient. Albert Einstein declared, "It is the supreme art of the Teacher to awaken joy in creative expression and knowledge." To ignite a passion for learning in others requires that an educator also brings forward value-added competence. Not only should we aim to educate the mind, but the heart as well. Successful educators demonstrate the abilities to challenge, encourage, inspire, and unleash the potential of their students. Developing and modeling these leadership skills is paramount to becoming influential as an educator.

4. Delivering Your Message
Being effective as educators calls us to be excellent communicators. In conveying your message there are always three presentations to consider: the one you deliver, the one you wanted to deliver, and the one your audience receives. The intention is to have these three come into alignment in order to engage participants in a meaningful learning experience.

Gaining proficiency and confidence in your presentation skills will take dedicated practice. Continue to fine tune your writing and public speaking skills in order to articulate your message clearly, concisely and with energy. Pay attention to the techniques used by those you deem as highly effective presenters. Toastmasters International is a nonprofit educational organization that operates clubs worldwide for the purpose of helping members improve their communication, public speaking, and leadership skills. Get out there, stretch yourself, and find your voice.

Capture your audience and develop strategies to maintain their responsiveness as you relay information. Frontloading, as an example, is a way of delivering the most relevant part of your message first. Make sure everyone quickly understands the big ideas of your message before diving into the details. Rambling creates frustration and could risk losing the attention of your audience. Convey information in an organized manner that leads to rapid clarity. Avoid overloading information. Structure your message by emphasizing a few key points and then add depth to each with supporting subpoints. Keep in mind that visual learning can be a powerful way to help people receive and integrate new information. Anytime you can show rather than tell, you’ll reduce the risk that your receiver might misconstrue or confuse the message.

PowerPoint has facilitated an easy delivery of our message, but we could risk boring our audience if we use too much text. If our approach lacks focus or becomes too wordy or dull we may miss the chance to earn the full attention of our audience. The text should serve to guide the presenter and audience with summary points. Be creative as you design your presentations with interesting and attractive visuals. Know when to use images, animation, and videos to help effectively communicate your message. Dr. Mary Beth Whitcomb has offered excellent advice on how to create engaging PowerPoint presentations and states, “although my techniques have evolved over the years, my philosophy was, and continues to be, that veterinarians are no different from toddlers transfixed on Sesame Street, in which the actors capture the kids’ attention with short, attractive, seemingly simple skits.”

Maintain a connection with your audience. Understand what is important to them and recognize how to deliver at their level of knowledge. Effective presenters have a way of reaching everyone in the room regardless of their previous level of knowledge. They also create a positive, candid tone that invites their audience to engage. If you come across as the condescending know-it-all expert you will likely lose your listeners. Strive to stay tuned into the needs of your audience as well. Do you need to speak across generational differences? Are you able to pick up the vibes of your listeners? Developing this sense of awareness will help you know when to adjust the pace, explain in greater detail, shorten your talk, invite participation, or actively listen.

Can you use a relevant story to get your point across? Stories can be inspiring, informative, and offer an invigorating break from the download of mind-numbing facts. Your story should be distinctive, have clear purpose, and resonate with the audience. Often, a story can help others process complex information in a way that connects the dots and brings new understanding. And you can have some fun with people.

As a final thought, learn how to be prepared but loose in your presentation style. That means letting go of perfection. Stop worrying about a flawless presentation. Your audience is more likely to relate with you as you “keep it real.”

5. Implementing Your Plan
Remain open and creative to possibilities as you seek a teaching appointment. Consider approaching Department Heads and Program Directors at targeted institutions to share your interests. Build upon your network of colleagues and friends to create connections. Be willing to volunteer your time. Perhaps this means offering a guest lecture or serv-
ing on an advisory committee for a teaching institution. As your interest, talent, and enthusiasm for teaching becomes evident, the right opportunity will become more likely.

Make yourself marketable. Demonstrate that you have an established track record with strong interest in teaching opportunities. A curriculum vitae should be provided when applying for a position in academia, whereas a resume is generally used for applying to positions in the industry. The curriculum vitae is a comprehensive document used in academic circles and medical careers that elaborates on education, publications, and other achievements. Present a cover letter, whether you are applying for a known position or inquiring about positions, to describe what sets you apart and why you might be a good fit for the teaching institution. Also be prepared to give a presentation as some hiring authorities may want to evaluate your public speaking skills. Research the program you are targeting so you can find areas of commonality between you and reveal the right fit.

Negotiating a letter of appointment will look different in each situation. When hired as an adjunct faculty, the position frequently begins part-time with reimbursement based upon the number of credit hours taught. Do not expect a high-paying salary and employment benefits. For many, the benefits come in other ways, such as the ability to have a flexible schedule. Full-time positions with all the benefits are obtainable. As you get your foot in the door, additional teaching opportunities may become available.

Find encouragement from those who have already successfully paved the pathway. Dr. Stephanie Brault reminds us to be persistent. In her case, she was facing a career transition while she and her husband were relocating a home, acquiring a new veterinary business and starting a family. Though it took 6 months, she purposefully was able to obtain a teaching appointment at a community college instructing health-care professionals, which offered her appropriate and timely employment.11 Dr. Elisabeth Giedt, presently the Director of Continuing Education for the Center of Veterinary Health Sciences at Oklahoma State University, reminds us to draw upon our network of friends. A client who was an alumnus of a small college initially recommended her as an instructor. This launched a successful transition for her from practice into an expanding career pathway in academia.12 Dr. Jerry Black inspires us to be ready to serve. In addition to his many years of active practice and entrepreneurship, he has a long list of involvements in teaching, serving, and leading national organizations. Specifically he was invited to participate within an advisory committee to review the curriculum and strategically plan for the Equine Sciences Program at CSU. Ultimately this led him to becoming the Director of the program. He describes the pathway as a “great opportunity for a second career”.

6. Concluding Remarks
Serving and building up others through the role as an educator is a privileged position and creates numerous advantages for everyone engaged in the learning experience.

From a viewpoint of practicality, making a transition into education may allow a stimulating new career pathway that supports a different lifestyle choice. For those who have served in the field as an equine practitioner, we recognize the demands of a job that require our mental, emotional, and physical stamina. Equine veterinarians are tough. And although we are respected for this resilience, we often find ourselves needing to adapt to changing situations throughout our career paths. Perhaps a physical health condition has created a new challenge to performing hind limb flexion tests. Perhaps a new child in your family changes your ability to go treat the colic in the middle of the night. Perhaps you are facing mental fatigue from 20 years of managing the expectations of others. Whether by default or design, being able to transition into teaching could be inspirational as you offer your gifts with a new approach.

Finding the right fit as a teacher can launch your unique talents. As veterinary doctors, we are accustomed to relaying information to our clients. As caregivers, by our nature, we are drawn to help others. As lifelong students of the veterinary profession, we are stimulated by continually advancing our knowledge. We continue to discover our interests and abilities as we evolve through our career path. Becoming actively involved as an educator may offer the perfect opportunity, allowing you to successfully share your knowledge and experience with others.

Teaching becomes a deeply gratifying mission. Being able to instruct, encourage, and influence upcoming professionals and contribute in their successes brings tremendous reward. As we distinguish the gifts of what we have to offer, we should be inspired to share them with others. As Woodrow Wilson once stated, “You are not here merely to make a living. You are here in order to enable the world to live more amply, with greater vision, with a finer spirit of hope and achievement. You are here to enrich the world, and you impoverish yourself if you forget the errand.”

Do not expect to do this alone. As educators we share the responsibilities to enhance the foundation of knowledge within our industry and help others achieve their goals. You should not be operating in isolation, but rather cooperation. Collaborating with partners who have unique talents in different areas and aligning team members toward a common vision becomes powerful in effect. Performance and results improve for the overall team when individuals are passionate and offering their talents and...
superior skill. An effective team can radiate possibilities to create an outcome greater than the sum of its parts.

Finally, create the classroom wherever you are! Participating as an educator is really about desiring to make a positive difference in the lives of others. Chose to become the visionary and realize that you could be that person who inspires another to a reach for a new destination.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

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Career Transition From Practice to Industry

Wendy Vaala, VMD, DACVIM-LA

Some career transitions are carefully planned whereas others can occur unexpectedly due to a wide array of changes in your personal life including marriage, starting a family, physical injury, or caring for aging parents. Clinical practice may no longer fit your needs in terms of work/life balance due to dissatisfaction with the practice culture, management strategy, financial stability, or the demands of a rigorous on-call schedule. Or you may have made a conscious decision to change career objectives. Given that there are few formal resources available to explore the questions and concerns that arise when contemplating a job within the animal health industry, this article offers an individual perspective about the pros and cons of such a career path and highlights some of the less recognized advantages. Author’s address: Merck Animal Health, S1476 Pleasant View Road, Alma, WI 54610. e-mail: wendy.vaala@merck.com. © 2016 AAEP.

1. Introduction

A veterinary education provides the foundation for a wide range of career opportunities, yet the resources needed to evaluate alternate career paths are not easy to find. Some career transitions are anticipated and planned for, whereas others become a necessity due to changes in personal life, dissatisfaction with current employment, burnout, boredom, or a combination. When I attended veterinary school I had my sights set on a career in clinical practice, not unlike the majority of today’s veterinary students. Following graduation, I pursued a large-animal internship followed by a large-animal residency in internal medicine leading to board certification. Three decades ago, specialty training groomed a clinician for a position in academia, given that there were relatively few private equine hospitals large enough to support multiple equine specialists. In academia, clinicians were encouraged to develop areas of clinical expertise and the awakening specialties of large-animal neonatology and perinatology became my focus. Academic practice provided a robust and varied caseload, a strong group of mentors from many specialties, as well as the politics, layered decision making, and some of the red tape that develops within large operations.

Following 15 years in academia, a change in personal life prompted a transition into private practice at two expanding, multi-person equine specialty hospitals with the goal of developing a medicine referral service and NICU at each facility. Private practice offered the rewarding opportunity to bring affordable neonatal care closer to the end user while challenging me to re-hone other internal medicine skills beyond the scope of equine neonatology. It was a memorable transition: leaving academia, where I had been a member of one of the largest equine internal medicine departments that included a workforce of interns, residents, and veterinary students, and entering a private practice, where I became a medicine department of “one.” But private practice also offered the support of a smaller, resourceful, and more nimble team of clinical spe-
cialists in surgery, reproduction, and sport horse medicine; one or more interns; visiting veterinarians and student externs; outstanding, cross-trained technicians; and a volunteer group of enthusiastic pre-veterinary student foal sitters. New areas of clinical interest emerged, including ophthalmology, ultrasonography, and neurology. No longer physically surrounded by multiple large-animal specialists, close relationships were forged with an even wider range of respected colleagues and new mentors who were only a phone call or email away regardless of their zip code whenever I was challenged by difficult or puzzling cases. That networking and feeling part a larger equine veterinary community was one of the unexpected highlights of private practice. Lecturing continued both at regional, national, and international meetings, as well as for clinic-organized events hosted for referring veterinarians and horse owners. Pharmaceutical companies occasionally invited me to give lectures in areas of my expertise. Unknowingly, I began to meet individuals who would later become a more integral part of the next, and unexpected, phase of my professional career.

In private group practice, the teamwork among clinicians, nurses, and interns often resulted in increased efficiency in terms of manpower and time when it came to many patient procedures. There was more direct accountability for patient care from admission to discharge that included diagnostics, treatments, and billing. But with fewer team members, there were more on-call emergency hours, especially during foaling season, which stretched from early winter into mid summer in the mid-Atlantic region.

But all aspects considered, private practice was extremely rewarding and my next transition did not occur because I was unhappy with private practice. It was a difficult decision. A move to industry was not planned until another change in my personal life included a long-distance move to the bluffs of western Wisconsin, where the nearest specialty practice or veterinary school was at least 2–3 hours away. Fortuitously, at a crossroad in my career, colleagues within industry approached me about a job opening as an equine technical service veterinarian and encouraged me to apply. The result was a second career transition from private specialty practice to a position in the animal health industry at Intervet, Inc.

2. Profile of an Equine Veterinary Career in the Animal Health Industry

The following description of a technical service (TS) veterinarian position in industry appeared in a recent DVM360 article entitled, “37 Ways to Use a DVM Degree”1 (published on DVM360.com. May 2016): “Technical services veterinarian: Lots of driving, meeting new people and learning more than you ever wanted to know about the minutiae of kibble manufacturing (or drug manufacturing depending on your company). It’s a different side of veterinary medicine, but immensely rewarding for those extroverted enough to enjoy all the meetings.” There is travel involved with most TS positions, but industry jobs open far more educational avenues for diverse training than this ‘tunnel-vision’ definition of learning suggests. Others view a veterinary job in industry as the last step before a cane and retirement while a polar opposite conception is that you should carry photographs of your spouse, family, pets, and back yard given that you will forget what they look like due to a relentless travel schedule. Fortunately, those are both misconceptions since there is far more diversity, flexibility, and career opportunity within industry for talented equine veterinarians with a wide variety of skill sets.

Within an animal-health company, the equine business unit exists either as a stand-alone business or as part of a larger unit composed of one or more specie teams. Some companies combine equine and companion animal species, whereas others group the equine team with the food animal business unit. The equine group includes TS veterinarians, a sales team composed of regional field-based representatives, as well as inside representatives who are office based and contact accounts via phone and emails, a marketing manager and associated advertising agencies, and the business unit director. Although there are different career options available, the most popular position for equine veterinarians is as a TS veterinarian. The American Veterinary Medical Association (AVMA) Market Research Statistics on US veterinary positions for 2015 (www.avma.org/KB/Resources/Statistics) reveal the following demographics for veterinary jobs in industry:

- In 2015 a total of 15,854 veterinarians were employed by the public or corporate sectors that included academia, federal, state, or local government, uniformed services, industry, and other public or corporate employers. Based on sex, 47.8% of those veterinarians were male and 52.2% were female.
- A total of 3324 veterinarians were employed specifically within industry (21% of the above population) with 56.9% males and 43.1% females.
- Based on a review of AVMA statistics from previous years, those percentages have changed only slightly since 2007.

Job responsibilities for a TS veterinarian include time in the field traveling with the sales team to visit with veterinarians individually as well as at larger group meetings. Discussions might cover a specific question about a product to an in-depth conversation about biosecurity in the midst of an infectious disease outbreak or an exploratory discussion to hear about unmet needs in equine vaccines or pharmaceuticals. On most of these trips the windshield time between clinic stops is spent...
conversing with a fellow team member/sales representative about the health of the local equine industry, answering questions about products ranging from mode of action of a dewormer to onset of immunity for a vaccine. The sales team becomes your surrogate family and friendships are forged. Other responsibilities include reviewing and helping create marketing and technical bulletins, preparing PowerPoint presentations and proceedings articles for upcoming conferences, developing webinars for veterinarians or lay personnel such as Pony Club members, researching topics of concern that arise during veterinary meetings, preparing an abstract or journal article for submission, helping design and monitor post-licensing market support trials, as well as completing more mundane tasks such as expense reports and online training modules. Figure 1 depicts additional networking that can occur depending on your interests, talents, and specific job description. TS veterinarians often work with research and development to address questions about vaccines or drugs in development. New ideas gathered from the field are directed toward business development. Some veterinarians will spend some time providing pharmacovigilance support to address all calls from veterinarians and owners regarding an adverse event or lack of efficacy concern involving a company product.

With the above job description in mind, it is not difficult to compose of list of helpful attributes for those considering a TS position:

- Good communication skills in a variety of situations ranging from casual one-on-one conversation with a colleague to formal lectures in front of large groups.
- Reasonable computer skills that include familiarity with creating PowerPoint presentations, hosting webinars, and navigating through spreadsheets.
- Willingness to travel and the temperament to tolerate the unavoidable travel delays and mishaps that are bound to occur.
- Enthusiasm for educating and sharing information with diverse audiences that include veterinarians, technicians, students, horse owners, and allied industry partners.
- Passion for learning given that the job may require tackling topics outside your area of expertise.

3. Frequently Asked Questions Encountered When Considering a Transition to a Job in the Animal Health Industry

Reservations that frequently arise when contemplating a change in jobs from private practice to industry include the following:

- Will I lose my clinical skill set and acumen honed by caring for patients on a daily basis?

An industry position provides the opportunity to attend and participate in a wider variety of conferences and CE events that might not have been possible in private practice due to a lack of time and emergency coverage. Additional training in areas of interest is supported if the need is justified. The job is what you make it. Rather than the drudgery and tunnel vision of learning only the minutiae about one company’s line of biologics and pharmaceuticals, the job allows you to expand your knowledge base and to dig deeper into areas of veterinary medicine that include immunology, infectious disease mitigation and surveillance, antimicrobial and parasiticide resistance, and new avenues of pain control. The quest for new technology in terms of vaccines, antibiotic alternatives, new strategies for prevention, and control of osteoarthritis are just a few of the challenges that can become your new crusade.

- Will I miss private practice including the patients, the clients, the staff, and the referring veterinarians? How will the corporate culture compare?

Based on results of a 2014 American Association of Equine Practitioners (AAEP) listserv members survey, three key features emerged as strong determinants for job satisfaction among practitioners: a healthy and compatible practice culture, the degree of control and choice they had over their individual professional lifestyle, and a manageable level of stress. The same factors can be applied to a career in industry. Animal health companies also differ in their corporate and species-specific team cultures. Personalities within equine groups consisting of veterinarians, sales representatives, the business unit director, and marketing manager, etc., will also vary.

Fig. 1. Examples of working relationships between technical services, other departments within an animal health industry company, and the veterinary community.
between companies. Important interpersonal relationships develop just as they do in practice. The opportunity to travel and visit a wide variety of practices throughout the country offers new and unique perspectives of equine practice that is rarely offered during a career forged within a single practice or one segment of the industry. Regional sales representatives become not only tour guides of their territories, but often an honorary family member.

- Will I be able to adapt to the change of pace and challenges of a job that might require considerable travel? How will I handle nights on the road away from home and family?

The rigors of a tedious travel schedule seem to loom at the top of real or perceived perils associated with a TS position within the animal health industry. TS positions may vary in the percentage of time spent on the road with 40–50% of your time spent traveling or attending conferences and lectures. Depending on the company, territory, and job description, some of that travel may encompass day trips that helps minimize nights away from home. In many instances, you control and design your travel schedule, which is preferable to the unpredictability of emergency on-call duties in private practice that can drag you away unexpectedly from a family event or long-anticipated home-cooked meal at a moment’s notice. One bonus of a busy travel schedule includes accumulation of frequent flyer miles and hotel bonus points that can be used for future family getaways. When not traveling, most TS veterinarians have the added benefit that they can work from a home office via webinars, conference calls, and emails.

- How will my specialty training or advanced degrees be valued by industry? Will my individuality be lost within a large corporate structure?

Marketing your attributes and clinical expertise and experience is up to you. Most TS jobs value formal specialty training, business degrees, and/or valuable years of clinical experience. The job market is competitive and veterinarians who have practical clinical experience are often preferred over new graduates for TS veterinary positions. Within the animal health industry there are a variety of career avenues to consider. A TS veterinarian spends considerable time supporting the needs of the sales team and their veterinary customers, provides valuable feedback about what equine veterinarians view as unmet needs within equine practice, as well as edits and/or writes TS bulletins and marketing pieces.

- What additional career paths exist for an equine veterinarian within the animal health industry?

In addition to a position as a TS veterinarian who supports the sales team and marketing with up-to-date data from personal expertise and company-sponsored market-support trials and time spent in the field riding with regional sales representatives, alternate career paths include managerial roles within the equine business unit and larger corporate structure, an active role within the research and development divisions if your background includes research training in key areas such as immunology or pharmacology, a managerial role in marketing or sales if you have a strong background in business and people management, pharmacovigilance that involves monitoring efficacy and adverse events involving the company’s equine product line, or a role in business development focusing on discovery and implementation of new technology. When joining a large corporation the worry of feeling like a small fish in a big pond can occur, but your talents and career goals can quickly align you with a smaller group of colleagues who become your new team.

- Will I lose my credibility as a clinician? How will my colleagues view my career change?

Frequent interactions with equine practitioners to discuss and offer solutions to practice problems and unmet clinical needs, opportunities to participate in a broad array of CE courses both as attendee and lecturer, time spent designing and evaluating results of market support trials are a few examples of how clinical expertise can be redirected. Job satisfaction is one of the best testimonies that a position within the animal health industry can be a rewarding career. Seeing a happy, motivated veterinarian in their new role intrigues many colleagues to re-think potential misconceptions of a job within the animal-health field. Whether you participate in the design of market support trials and present the data generated or render advice to business development personnel regarding pursuit of new products or technologies, you may find yourself interacting with respected colleagues in new ways that serve to strengthen existing relationships. Loss of credibility is rarely an issue if the job fits your aspirations, talents, and work/life balance.

- Will I lose control over my career or lose my job through unexpected corporate mergers and acquisitions?

The one variable that cannot be controlled is the prospect of future corporate mergers, acquisitions, or divestitures. But, private practice also carries with it the threat of new competition and/or a declining client and patient base.

- Is this a financially sound move?

Industry jobs provide a good base salary that is often supplemented by bonuses based on the business
unit’s and animal health company's performance. Base compensation is usually determined by an employee's actual position in the marketplace and sustained performance over time, as well as development of skills and abilities. Incentive pay might include bonuses that motivate employees to achieve high levels of performance for both the individual and the company. Long-term incentives include equity-based incentives that recognize future potential for significant contribution to the company.

There are comprehensive health benefits packages (including dental and vision), and a 401(k)/pension/retirement plan. In addition to major holidays, there are usually good vacation packages. Without the worry of after-hour emergency calls or a clinic full of patients, vacation time may become more relaxing and that is priceless.

- What skill sets will this new position require?

Good communication skills are a fundamental requirement. An industry job includes many personal conversations with veterinarians face to face, by phone, or by email. There are countless teachable moments when riding with sale representatives who are often experts within certain segments of the equine industry and are hungry for more scientific knowledge to improve their customer relationships. There are numerous requests for informal, small-group presentations as well as formal lectures in front of larger audiences at regional or national veterinary conferences. Technical expertise is also helpful and includes a comfort level with creating PowerPoint presentations, hosting internal and external webinars, or sorting through Excel spreadsheets containing trial data. A flair for technical and scientific writing is always a welcome talent.

- Can I continue to make valuable and satisfying contributions to the veterinary profession?

Without the constraints of emergency duty, a busy patient caseload, and other day-to-day and after-hour responsibilities associated with private practice, you are able to pursue valuable volunteer opportunities within a range of veterinary organizations including service on committees or taskforces within the AAEP, AVMA, specialty colleges, or state and regional veterinary organizations. There may be time to participate on an equitarian mission or author a scientific article for a peer-reviewed journal or a book chapter or become more involved in public policy or equine welfare issues. In practice we often focus on the welfare of one patient at a time. Within industry we have the opportunity to influence the lives of many, whether working on the development of a new vaccine or sharing new data about disease management with our colleagues.
What to Do if You Are Contemplating a Job in Industry

Given that there are few formal Internet resources that provide specific answers about industry jobs, individuals interested in learning more about a career in industry should not hesitate to reach out to as many veterinarians currently employed by an animal health company as possible to gather a wide array of opinions, advice, and perspectives. The annual AAEP convention offers an ideal opportunity to make those contacts. Visit the Web site of major animal-health companies to read about the company and its mission statement as well as learn about the range of career opportunities that may be of interest. A few of the benefits and challenges of a TS position are presented in Table 1 and may trigger additional questions if you are considering a transition.

My transition from a busy private practice on the East coast to an industry position that allowed me to reside on a quiet farm on the bluffs of western Wisconsin was not a change I would ever have foreseen as an internist kneeling over a dummy foal on a ventilator in the NICU at New Bolton Center nor as a clinical associate in private practice. I am privileged to work with one of the most awesome group of people I have ever met. Their motivation, love of the horse, and commitment to those who care for them, as well as their integrity in everything they do, makes this job more of a gift than work.

Acknowledgments

The author gratefully acknowledges the insight and opinions shared by two respected colleagues, Drs. Earl Gaughan and Bryant Craig, who have chosen similar transitions from academia and/or private practice to a career in the animal health industry.

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author is currently employed by Merck Animal Health as an Associate Director of Life Cycle Management – Equine.

References

Transitioning From Clinical Practice Into a Government Career

Rachel Cezar, DVM

1. Introduction

Almost 28 percent of veterinarians in clinical practice might seek to transition to a nonclinical veterinary career at some point in the future or are currently seeking such a transition, according to a 2013 survey spearheaded by the 2013–2014 class of the American Veterinary Medical Association (AVMA) Future Leaders Program: https://www.avma.org/ProfessionalDevelopment/Personal/CareerTransitions/Pages/default.aspx.

Over 4000 veterinarians work for the local, state, and federal government as clinical practitioners, researchers, inspectors, and other professions. More than half of the veterinarians in the federal government work for the various agencies in the U.S. Department of Agriculture, including the Animal and Plant Health Inspection Service and the Food Safety and Inspection Service. A few other federal agencies that employ veterinarians are the Food and Drug Administration, Centers for Disease Control and Prevention, National Institutes of Health, Environmental Protection Agency, and the Department of Homeland Security. Veterinarians also serve in the military and the Commissioned Corps of the U.S. Public Health Service.

Their work may involve treating animals for injuries and illnesses, conducting clinical research on human and animal health problems, getting rid of major animal diseases, promoting public health, inspecting livestock or food products, enforcing food safety regulation, or managing and administering programs. Veterinarians specifically in the federal government earned an estimated mean annual wage of $89,480 in 2015, according to the U.S. Bureau of Labor Statistics.

But what you may not expect is that government veterinarians go into space with NASA and perform surgery on elephants at the National Zoo. Veterinarians can also be elected to Congress. Currently, Dr. Kurt Schrader, a Democrat from Oregon, Dr. Ted Yoho, a Republican from Florida, and Dr. Ralph Abraham, a Republican from Louisiana, serve in the U.S. House of Representatives.

Successfully making a government career transition requires self reflection, courage, and persistence. I had to do some sincere reflection on transitioning from practice to a government career because many would say that you are not a veterinarian if you are not practicing. I realized that was not the case. Beginning my career early in government allowed me to contribute even more to the livelihood and well being of horses and clients. Another advantage was I did not have to get an additional degree beyond the DVM. That is the wonderful thing about our veterinary degree.
A veterinary education prepares us to do so much more than traditional veterinary practice. Therefore, after finding a field of interest in the government, it is important to network to learn more about the field and get to know people. Steps can include informational interviews, shadowing, volunteering, or internships. Social media connections such as LinkedIn (https://www.linkedin.com/) has been an invaluable source for me to meet individuals that I would like to work with throughout my career.

Résumé writing is another important piece of a career transitioning to the government. You need to explain how your background applies to the new position. Clinical practitioners develop all sorts of skills, from communications to the control of infectious disease. More importantly, the federal government does not want a one-page résumé. It is imperative you provide all the training and experience you have developed ever since you graduated from veterinary school and even activities you do outside your normal workday. Many of us volunteer for committees and task forces and do not ever realize how that is also part of our growth of leadership, communicating effectively and building relationships.

When looking for a position within the government, it is important to learn about ways to search for all positions that are suitable, not just ones that are specifically listed as requiring a veterinary degree or clinical experience.

The top database for federal government jobs is USAJOBS (www.usajobs.gov). What follows are hints on how to look for government jobs in this database.

There are several terms that are helpful to know when navigating and conducting searches on the USAJOBS Web site:

The first term is “General Schedule” (GS) level. A GS level is the federal government’s way to keep salaries consistent among federal agency jobs and make sure there is equal pay for equal work. There are currently 15 grades and 10 steps. For the GS salaries for 2016, visit the following link: https://www.opm.gov/policy-date-oversight/pay-leave/salaries-wages/2016/general-schedule/. Veterans should search for GS grade 11 or higher when setting search parameters. Typically, new graduates start at GS grade 11 step 1; however, most positions move up to the next grade the next year and you are qualified to apply for the next grade. I started actually at a GS grade 9 step 5 and in 5 years I moved up to a GS grade 14 step 1 in which I doubled my salary.

The second term to know is “series,” which is the term for certain job classifications within USAJOBS. Using the appropriate series numbers as well as broad term key words will help to identify job listings that may be suitable for veterinarians. Visit http://www.opm.gov/fedclass/ for a complete explanation of this classification and grading of federal jobs.

The federal government series numbers that may be appropriate for veterinary-related jobs are as follows:

- 400 series (Wildlife/Conservation/Department of Interior)
- 600 series (specifically 601-General Health Science)
- 700 series (specifically 701-Veterinary Medical Science)
- 1300 series (Physical Science)
- 1800 series (Inspection, Investigation, Enforcement and Compliance)

Some of the broad word criteria or keyword terms that can help locate jobs are below:

- Animal
- Biodefense
- Biologist/Biology
- Chemist/Chemistry
- Epidemiologist/Epidemiology
- General Health Science
- Health Scientist
- Medical Officer
- Microbiologist/Microbiology
- Public Health Program Specialist/Public Health
- Veterinary Medical Officer
- Veterinary
- Wildlife
- Zoonotic

To find a job at USAJOBS, you can either enter search criteria each time, or you can set up a “Client Account” through which you can save different searches based on combinations of criteria you select. With the client account, you can even set it up so that you are automatically e-mailed when jobs meeting your criteria are posted on the site, saving you the time of actively searching for them.

The search criteria you use may be as wide or narrow as you like. Performing a search using key words such as “animal,” “wildlife,” or “epidemiology” will produce a wide variety of potential jobs, for some of which veterinarians will be overqualified. Narrower searches, such as using the series number, job title such as “veterinarian,” “veterinary medical officer,” “animal scientist,” or other specification, will yield fewer but more targeted job postings. Further narrowing the search criteria by GS level, location, or other factors will provide an even more precise listing of the desired jobs available.

Also, setting up a “Client Account” on USAJOBS will allow you to upload your resume so when positions are posted that you are interested in, you can apply immediately. This is important because some positions only allow the first 30–50 applicants to apply or are only open for 1 week.
Other helpful resources for learning more about veterinary career opportunities in the government are below:

1. **AVMA Webinar: Finding & Applying for Veterinary Federal Jobs:** This webinar was put on by the AVMA’s Career Center and provides practical guidance on the whole intimidating process of landing that cushy government job. Watch the recording of the webinar on YouTube at the following link: http://youtu.be/sGau7fYfWQg.

2. **U.S. Animal Health Association Job Board:** This online bulletin board (http://www.usaha.org/Reference/BulletinBoard.aspx) is updated frequently with unique veterinary jobs not only with the federal government but also state governments, Native American tribes, universities, and more.

3. **National Association of Federal Veterinarians:** Learn more about their work and mission at the following link: http://www.nafv.org/AboutUs.html.

Transitioning to a career in the federal government will allow you to not just treat one animal at a time but a whole nation of animals and humans. It’s all about making sure you develop your résumé around what you learned and achieved within your career lifetime, not just what you have done in practice. And do not believe you will need another degree to transition to a different career in the veterinary profession. Trust that your veterinary degree can take you places you never expected.

**Acknowledgments**

*Declaration of Ethics*

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

*Conflict of Interest*

The Author declares no conflicts of interest.
Planning for Unexpected Transitions: Disability Lessons Learned

Marjorie W. Miller, DVM

Short-term, long-term, and permanent disability can pose significant financial, physical, emotional, and psychological threats to equine veterinarians and veterinary students. The purpose of this paper is to help veterinarians prepare for and navigate through this unexpected transition. Author’s address: 2307 64th Street Court East, Bradenton, FL 34208; e-mail: blumoon9@gte.net. © 2016 AAEP.

1. Introduction

No one likes to think about the possibility of becoming disabled. Equine veterinarians accept the risks of working with horses just as people accept the risk of driving a vehicle. Risk is a part of life. During the Problems Facing Veterinarians in Small Practices Table Topic held at the 58th Annual Convention of the American Association of Equine Practitioners in Anaheim, California, the subject of disability was raised, and an informal poll revealed the vast majority of veterinarians participating had no long- or short-term disability insurance. Many of these veterinarians had recently opened solo practices and borrowed money to pursue the dream of owning their own business. Hopefully, the dream was not blindsided by an unexpected transition into a disabling illness or injury.

According to the United States Social Security Administration, 25% of current 20-year-olds will become disabled prior to reaching the age of 67 years. An illness or accident will keep one in five workers out of work for at least a year before the age of 65 years. More than 37 million Americans, 12% of the total population, are classified as disabled with more than 50% of these being in their working years from 18–64 years of age. “Less than 5% of disabling accidents and illnesses are work related; the other 95% are not, meaning Workers’ Compensation does not provide coverage.” It is common for people to associate disability with serious accidents, but in reality the majority of disabilities are caused by illnesses. Even people who do not have a high-risk job are at risk from disability from musculoskeletal, cardiovascular, cancer, psychiatric, or other illnesses. Sixty-nine percent of the workforce in the private sector has no long-term disability insurance.

Table 1 presents the disability claims filed by participants in the American Veterinary Medical Association Group Life Insurance Trust (now known as AVMA Life) during 2014 and 2015. Table 1 presents the disability claims filed by participants in the American Veterinary Medical Association Group Life Insurance Trust (now known as AVMA Life) during 2014 and 2015. It is important to note that the data reflect only veterinarians who are members of the American Veterinary Medical Association who have purchased disability insurance from AVMA Life. Differentiation of disability due to accident or illness cannot be provided due to the privacy and security of medical information under the Health Insurance Portability

NOTES
and Accountability Act (HIPAA), and there are no demographic data as to practice type. In a German study, the rate of accidents reported to an insurance database was 2.9 times higher for veterinarians than for physicians in general practice.6 In a study commissioned by the British Equine Veterinary Association and conducted by leading medical professionals at the Institute of Health and Wellbeing and the School of Veterinary Medicine at the University of Glasgow, 620 equine veterinarians completed a work-related-injuries questionnaire. The results of the study suggested that an equine vet could expect to sustain between seven and eight work-related injuries that impeded them from practicing, during a 30-year working life.7 Equine practice is a physically demanding, hands-on activity requiring quick reflexes, and in the event of an injury or illness, the ability to earn an income can be lost. In most instances, there is no “desk duty” where one can transition during convalescence and recovery. The financial repercussions can be disastrous unless one has planned ahead as prolonged loss of earned income can also result in decreased retirement income given that Social Security benefits are dependent upon the stream of lifetime earnings, and IRA or 401k contributions may not be possible in the absence of earned income. Financial pressures increase if there are extensive medical bills, and the stress of the injury or illness combined with financial stressors can lead to emotional and psychological distress. The data demonstrates that there is a significant risk of disability during one’s career, so it is necessary to protect future income.

2. Solution

The equine veterinarian needs to be prepared and plan ahead for the worst-case scenario by purchasing both health care insurance with comprehensive catastrophic coverage and long-term disability insurance. These coverages are the financial life rafts for economic survival during a disability, and coverage must be in place prior to the occurrence of any accident or illness.

Long-term disability insurance helps to safeguard self-employed veterinarians and their families from debt and a total depletion of savings. Veterinarians employed by private practices, public institutions, and corporations must know what benefits are provided as part of their benefit package and determine whether these benefits are adequate in the event of long-term or permanent disability.

There are disability income insurance policies available for veterinary students who are not earning income that cover tuition, student loans, and provide income in the event of disability. Supplemental Disability Income policies are also available for purchase to cover student loan obligations for recent graduates.

If a veterinarian is in private practice, whether as a solo practitioner or in a group practice, how will the practice expenses be paid during a long-term disability? Common expenses such as rent, equipment payments, staff salaries, answering service, electric, telephone, etc. will continue. Professional overhead expense insurance can be purchased to cover the business expenses and keep the business operational.

In the case of all insurance policies, it is imperative to understand what is covered, what is excluded, the duration of coverage, the commencement of payment of benefits, and the duration of benefit payments. Always read the fine print and ask questions of the insurance agent and other veterinarians. One needs to know how disability is defined, if there are residual benefits that pay the difference between what one earns as one transitions back to full-time work, and what was being paid in disability payments. Determine whether there is own occupation coverage that pays full benefits if one is able to return to work in a profession other than veterinary medicine.

Seeking the advice of a certified financial planner is prudent at any stage of life. A certified financial planner is a professional who is held to rigorous ethical standards and has completed extensive training and experience requirements. Quite simply, a certified financial planner serves his or her clients in the management of wealth and risk for their families and businesses, and can assist the veterinarian with an individualized plan to help with budgeting, investing, planning for retirement, saving for education, and how to best manage taxes and insurance coverage through all stages of life. Minimal investable assets may range from $0 to in excess of $500,000, and these professionals typically work for a fee plus commission. The importance of having investments or savings to tide one over until disability benefits begin to be paid cannot be overemphasized, and working with a certified financial planner will help the veterinarian stay on top of short- and long-term goals through the many changes that occur during a lifetime.

With the financial house in order, the veterinarian can now focus attention on who will provide care for the clients’ animals. In the multi-doctor practice, this is generally covered by everyone shouldering a heftier load or bringing in an associate. For the solo practitioner, getting together with colleagues and working out a plan in advance of any illness or accident is the ideal situation. Legible, accessible and accurate medical records will allow for continuity of care. Do not forget that the cur-

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rent and accessible medical records also apply to the veterinarian-owned horses, dogs, cats, etc.

The shift from veterinary doctor to patient is difficult, and the uncertainty of the return to work, the impersonal nature of the human medical system, the endless waiting for medical appointments, physical therapy, and/or occupational therapy, the pathology of the underlying condition causing the disability, and the potential undesirable adverse effects of medications can lead to the development of physical and emotional discomfort and distress. Dr. Ann Dwyer’s article, “Coming Back After Injury or Disability: Advice for Equine Practitioners”8 chronicles her journey through a serious injury, and every veterinarian ought to read this paper. Dr. Dwyer talks about facing the “dark days,” the days where anger, frustration and self-pity come to visit, and she emphasizes the value of a positive attitude. Clients, associates, friends, and family will step up in amazing ways to help, and in most cases, the veterinarian will heal and return to practice. There is a small subset of veterinarians, however, who will come to find that they will never return to equine practice, and this realization gives new meaning to the concept of the dark days. Equine practice is not just a job; it is a lifestyle and a vocation. There are ways to stay involved despite the inability to practice. If there is an economic hardship that can be demonstrated, both the American Association of Equine Practitioners (AAEP) and the American Veterinary Medical Association (AVMA) have forms that can be submitted requesting a waiver of dues. Remaining a member of the AVMA is a requirement to maintain benefits if participating in the insurance programs offered by AVMA Life. The ability to remain a participant or lurker on the various AAEP List Serves keeps one connected with the community of equine veterinarians.

3. Discussion

Workers’ Compensation, also known as Workman’s Comp, is a state-mandated insurance program that provides compensation to employees who suffer job-related injuries and illnesses. The requirement to purchase Workers’ Compensation varies from state to state. Workers’ Compensation provides coverage for medical expenses, lost wages from time off work, rehabilitation, compensation for permanent impairments, and occasionally, job retraining. Workers’ Compensation can provide money and benefits to an injured worker in the form of temporary disability and permanent disability payments. In the case of a workplace death, Workman’s Compensation provides a death benefit to the estate of the deceased.

Social Security Disability Income (SSDI) is a federal program that pays benefits if the person is deemed completely disabled according to the Social Security Administration’s definition of total disability and the person has worked and paid the Federal Insurance Contributions Act (FICA) premiums. It is not unusual for the approval of SSDI benefits to take up to 2 years. To meet the criteria of total disability under the Social Security Administration’s definition, a worker cannot do the type of work that was done before, cannot perform other work due to the medical condition, and the disability will last at least 1 year or result in death.

Supplemental Security Income (SSI) is a Federal income supplement program funded by general tax revenues designed to help aged (> 65 y), blind, and disabled people who have little or no income to provide the basic need for food, clothing, and shelter.

Workers’ Compensation and SSDI claims may require the assistance of an attorney, and as explained above, the veterinarian may not qualify for any benefits.

Long- and short-term disability insurance guarantees that a benefit of known value is paid within a designated period of time. If the disability premium is being paid by the employer, the benefits will be taxable. With a plan paid for with after tax dollars by an individual, the benefits will not be taxed, and the policy is portable if the veterinarian leaves the practice. If a veterinarian becomes disabled and is unable to work for 2 or 3 months, short-term disability insurance may be indicated if there are insufficient savings to cover living expenses during that time. Long-term disability insurance provides income for an extended period of time if the veterinarian is unable to work or can only work part time. Young veterinarians must note that a “25-year-old worker who makes $50,000 a year and suffers a permanent disability could lose $3.8 million in future earnings.”9 Any person who has a job should consider purchasing long-term disability insurance.

It is very important to have a primary physician and to make the time to go in for the annual well visit. Medical conditions that are diagnosed early typically have better outcomes. Developing trust in a doctor takes time, and having a medical advocate is invaluable in the event of a severe injury or illness. If the doctor owns, has owned, or has been around horses, this is an added bonus as there will typically have better outcomes. Developing trust in a doctor takes time, and having a medical advocate is invaluable in the event of a severe injury or illness. If the doctor owns, has owned, or has been around horses, this is an added bonus as there will be familiarity with the job requirements of the equine veterinarian.

In summary, purchasing a health insurance policy with catastrophic coverage and a long-term disability policy will keep a person financially afloat during a prolonged disability. This will alleviate the stress associated with exhausting savings and investments and taking on debt. One may still have to pare down nonessential items to budget for the change in financial circumstances. Working with a certified financial planner may help to position the veterinarian better to withstand a decrease in earnings. Having a worst-case scenario plan in place with area veterinarians and maintaining good medical records will allow for a smoother transition of patient care. Making time to find a personal doctor...
and go for an annual checkup will ensure the best possible health. Staying in contact with friends, family and colleagues will raise your spirits and promote a positive outlook. Find something that gives your life meaning. Finally, nothing is better for the soul than being around a horse.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

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References and Footnote


*Personal communication, Felicia Watson, Trust Representative, AVMA Life, February 26, 2016.
Transitioning Away From the Daily Adrenalin Rush of Equine Practice—Retirement

Justin B. Janssen, DVM

1. Introduction

Equine practitioners should start early developing their retirement strategy. Retirement requires more effort than building a practice.

The goal of this presentation is to encourage all ages of veterinarians from the recent graduate to the seasoned American Association of Equine Practitioners (AAEP) member to begin today planning their retirement. Each individual’s situation and choices will be different. Are most busy equine practitioners unknowingly addicted to the daily adrenalin rush of just getting through the day? Does this addiction to adrenalin and the desire to continue building the practice prevent us from considering or planning our stepping away from our chosen avocation?

In a 2015 report by Blach et al,1 an economic survey of nearly 500 AAEP members found that at least 60% of practice owners are personally concerned about stress, retirement, and financial security. Forty-two percent worry about being able to sell the practice.4

AAEP as an organization and our equine practitioner colleagues often do not provide good role models or education about retirement. Many of our classic AAEP mentors seem to be the sage practitioners/members who continue to contribute to our profession by actively practicing and seem poised to transcend into heaven on their last farm call.

Each individual veterinarian’s situation is unique and different, but there are some shared common concerns:

- Financial: income, insurance, succession planning, social security, retirement funds
- Spouse/family relationships
- Physical: lifestyle, health status
- Psychological: a male veterinarian’s personal identity is closely linked to being a veterinarian. “We are what we do.” Can we give up our “status”?
- Religion/spiritual
- Hobbies, interests, volunteerism, passion
- Location: is retirement in our minds associated with a physical relocation?

This presentation will share the input of successful retired AAEP members who have chosen to retire while still alive! Their insights as to how long they worked arranging their retirement, what they enjoy most about retirement, and advice to other veterinarians will be presented.

The take-home message for the equine practitioner is to start early developing their retirement
strategy. Retirement requires more effort than building a practice.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

Reference
Transition From Practice to Ministry

Rev. F. Richard Lesser, DVM, MDiv

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1. Introduction
My wife, Marilyn Schmidt, and I started the Equine Clinic at Oakencroft in upstate New York and western Massachusetts in 1986. Over the years it grew to a nine-doctor practice that had offered services to 45,000 horses owned by 10,000 clients. I was a jack-of-all trades kind of a veterinarian, and I loved the work, the horses, and our clients. But after Marilyn died in 2005 I came to realize that I was supposed to be doing something else.

2. Selling the Practice
Like many other closely held operations, the practice had evolved into a blend of our professional life and our home life. We maintained a broodmare band for a major client that evolved into a separate but not very distinct entity. Having that farm business allowed us to fold some personal horses and cattle and sheep into the operation as well. Given that we were the only two partners, none of that mattered much, until it was time to sell. Do not underestimate the time and effort it takes to “clean up” the business so that the new buyers can comfortably know what they are buying. For us, that took 3 years, and the help of a practice consultant and a lawyer.

Finding buyers took even longer. Shortly after Marilyn died, I needed to decide what my plans would be going forward. I still had one child in middle school, one in high school, and one just starting college. I could not afford to just quit, but I also could not work the hours I had been working and still take care of the kids and myself. I looked for promising young associates, and hired four to cover the workload. During the next several years we had some staffing changes, always keeping in mind that I needed (in my mind) to sell the practice internally. That meant that the practice would need to be able to evolve from what we had started to what the new folks wanted. I worked with the potential new owners for 5 years to make that happen.

Once the buyers were identified, I began to slowly hand over more information and decisions to them. We took the whole practice team (doctors, lay staff, farm staff) on a 3-day retreat to facilitate the changes. Watching the changes happen was both exciting and sad.

3. Off to the Seminary
The discernment of a vocation to the priesthood is more about what God is asking than it is about trying to decide “what I want to do next with my life.” When I accepted that becoming a Catholic priest was God’s plan, I moved to fold up the parts of my life that I would be leaving behind. This took several years, and as a matter of faith, I can see the hand of God at work all along the way. In the end, I worked on my Masters in Divinity while the kids
got into college. My diocese has an upper age for newly ordained, and I was at that limit. If I had waited for their final decision, I would have frankly been too old. So, before I was accepted into the seminary, I sold the practice, helped with the transition, rented out the farm, handed off my roles in the American Association of Equine Practitioners (AAEP) and Veterinary Study Groups 7 and 20, and took a 3-month road trip to visit family and friends. It was a leap of faith appropriate to my new role.

I then spent a year working in a parish and 2 more years in the seminary. I found that much of the service ethic that resonates with veterinarians transferred directly to my new life of ministry. In a very real sense, my time as a veterinarian and my activity as an AAEP member were preparatory and foundational for my new life as a priest.

4. Epilogue

It is beyond the scope of this paper to explore priesthood. In any event, I doubt that many are headed in that direction. But for each of us, there comes a point of reflection about what we might do when we finish practice. The answers will be as varied as the number of members we have, and that is wonderful. Every member of the AAEP has developed personal cultures, mindsets, skills, and interests that are directly transferable to other activities. For some that will revolve around giving back through volunteer work or teaching. Others will take the opportunity to be there for family and friends. Others may find a whole new path. The AAEP has long held that in the moment that we have to make a big decision, we ask ourselves the question, “What is in the best interest of the welfare of the horse?” That selfless question has served our profession well. Going forward, we might ask a corollary question, “What should I do with what I have been gifted with so far in my life?”

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.
Extended Trot Fetlock Kinematics on Measured Dirt and Synthetic Arena Surfaces

Jill S. Thornton, DVM; Jennifer E. Symons, MS, PhD; Tanya C. Garcia, MS; and Susan M. Stover, DVM, PhD, DACVS*

Fetlock extension was greater on the arena surface that had the greater maximum impact force. The mechanical behavior of arena surfaces cannot be deduced from surface material type alone. Authors' addresses: J. D. Wheat Veterinary Orthopedic Research Laboratory, University of California–Davis, Davis, CA 95616 (Thornton, Garcia, Stover); Symbiomechanics LLC, Beaverton, OR 97078 (Symons); e-mail: smstover@ucdavis.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Suspensory ligament injuries are common in dressage horses and are thought to affect young horses offering the extended trot. Fetlock extension increases suspensory ligament strains. Fetlock extension differed in racehorses galloping on different surfaces. This study compared fetlock extension in dressage horses at the extended trot between synthetic and dirt arena surfaces.

2. Materials and Methods
Fetlock angle was measured from two-dimensional, high-speed kinematic videos of six dressage horses traveling at the extended trot on a synthetic arena surface and on a dirt arena surface. Surface mechanical behaviors were characterized using an equine surface-testing device. Maximum fetlock angle and maximum impact force were compared between surfaces using mixed-model ANOVA that when appropriate accounted for surface, horse velocity, and repeated measures within horse.

3. Results
Maximum fetlock angle was greater on the synthetic surface than dirt ($\Delta = 2^\circ; P = .025$). The maximum impact force of the synthetic surface was 41% greater than the dirt surface ($P = .006$).

4. Discussion
Arena surface material affected maximum fetlock angle in dressage horses performing the extended trot. Fetlock extension was greater on the surface that had the greater peak impact force. Surface properties have the potential to affect risk for suspensory ligament injury.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

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Effects of Alpha-2 Adrenergic Agonists With or Without Butorphanol on Subjective and Objective Lameness Assessment

Valerie J. Moorman, DVM, PhD, DACVS*; Luke Bass, DVM, MS, DABVP; and Melissa R. King, DVM, PhD, DACVSMR

Low-dose detomidine and romifidine in combination with butorphanol have a significant effect on subjective and objective lameness assessment, and thus their use to aid lameness assessment should be avoided. Authors’ address: Orthopaedic Research Center, Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: valerie.moorman@colostate.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
The gold standard of lameness localization is often accomplished with regional anesthesia. However, some horses are dangerous to themselves, the veterinarian, and handler during this process, even with appropriate manual restraint. The use of low doses of sedatives may improve safety for all individuals during these procedures. We hypothesized that administration of alpha-2 adrenergic agonists (xylazine, detomidine, and romifidine) would not significantly influence lameness, but the addition of butorphanol would have a significant effect on lameness.

2. Materials and Methods
Sixteen polo horses with naturally occurring lameness were evaluated before and following the IV administration of saline, xylazine (0.33 mg/kg), detomidine (0.007 mg/kg), romifidine (0.033 mg/kg), and the three above alpha-2s with the addition of butorphanol (0.007 mg/kg). Subjective and objective data were collected prior to treatment, and at 10, 15, 20, 30, and 40 minutes following injection. Data were analyzed with mixed-model ANOVA with significance set at $P < .05$.

3. Results
Use of detomidine and romifidine in combination with butorphanol resulted in significant changes in subjective hindlimb, but not forelimb, lameness. Objective variables were altered more commonly with detomidine and romifidine either alone or with butorphanol.

4. Conclusions
Xylazine, either alone or in combination with butorphanol, seems to have fewer effects on both subjective and objective assessment of equine lameness.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
This study was funded by Boehringer Ingelheim.
Acetaminophen/Paracetamol Efficacy in a Reversible Model of Equine Foot Pain

Jonathan H. Foreman, DVM, MS, DACVIM (LAIM)*; Catherine R. Foreman, DVMa; and Benjamin E. Bergstrom, DVMb

Acetaminophen provides foot pain analgesia comparable to oral flunixin. Authors’ address: College of Veterinary Medicine, Department of Veterinary Clinical Medicine, University of Illinois, 1008 West Hazelwood Drive, Urbana, IL 61802; e-mail: jhf@illinois.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
There are no refereed blinded controlled documentations of skeletal analgesic efficacy of acetaminophen in horses. The objective was to test the hypotheses that oral acetaminophen and flunixin meglumine (FM) are comparable in efficacy and are more efficacious in alleviating lameness than negative control in an adjustable heart bar shoe model of equine foot pain.

2. Materials and Methods
Eight healthy adult horses (5 Thoroughbred, 3 Quarter Horse; mean age, 8.3 ± 0.9 y; age range, 4–13 y) randomly underwent weekly oral treatments 1 hour after lameness induction. Treatments were negative control, FM (1.1 mg/kg), and acetaminophen (20 mg/kg). One investigator who was unaware of treatment assignments monitored heart rate (HR) and lameness score (LS) every 20 minutes for 5 hours after lameness induction and then hourly through 12 hours after treatment. One and 2 weeks later treatments were shuffled and the experiment was repeated. Repeated measures ANOVA and post-hoc Tukey’s test were used to identify analgesic effects at a significance level of $P < .05$.

3. Results
Post-treatment acetaminophen HR (2.7, 4, 4.3, 9, 10, and 11 h) and LS (2.7, 3, and 5 h) were lower than negative control ($P < .05$). FM HR (2.7 and 9 h) and LS (3.3, 4, 5, 6, 7, 9, and 10 h) were lower than negative control ($P < .05$). Acetaminophen and FM were not different from one another.

4. Discussion
It was concluded that acetaminophen at this oral dosage was comparable to FM and both were more efficacious than negative control.
Acknowledgments
Partial funding provided by the Fédération Équestre Internationale.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

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bDr. Bergstrom's current address is School of Veterinary Medicine, Purdue University, West Lafayette, IN 47907.
Assessment of Digital Venograms in Non-Laminitic Horses

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Digital venography in horses without known digital pathology demonstrates slight variations in the vascular pattern of the equine foot. Obtaining a full series of images, including early and late lateral views and weight-bearing and non-weight bearing images are necessary when assessing the vascular pattern in all horses. Authors’ addresses: Louisiana State University School of Veterinary Medicine, Baton Rouge, LA 70803 (Leise); Littleton Equine Clinic, 8025 S. Santa Fe Drive, Littleton, CO 80120 (Miller); Colorado State University College of Veterinary Medicine, Fort Collins, CO 80521 (Moorman, Bass); Innovative Equine Podiatry and Veterinary Service, 500 Rice Road, Collinsville, TX 76233 (Pittman); Midwest Equine, LLC, Columbia, MO 65205 (Rucker); International Equine Podiatry Center, PO Box 507, Versailles, KY 40383 (Redden); e-mail: bleise@lsu.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Venography is frequently used to assess vascular perfusion in the hoof. However, interpretation of the venogram remains subjective. The purpose of this study was to evaluate venographic technique in athletic, non-laminitic horses and to describe variations in the pattern.

2. Materials and Methods
Horses were evaluated for lameness and survey radiographs were obtained for each foot. Venograms were performed in both front feet of 23 horses. The amount of contrast and time required for infusion was recorded for each foot. Survey radiographs were evaluated for bone and hoof angle, palmar angle, and sole depth. Venograms were graded for contrast distribution throughout the digital vasculature.

3. Results
A total of 45 venograms in 23 horses were successfully performed. Amount of contrast infused in each foot averaged 22.9 mL. All radiographic images were obtained within an average of 97 seconds post-infusion. Horses with increased sole depth had improved detail of the terminal papillae. Fourteen feet had decreased contrast in the dorsal lamellar vessels on the early weight-bearing view, but contrast returned to this region when viewed on the unweighted lateral.

4. Discussion
Variation in the venographic pattern can be related to hoof conformation and weight-bearing; however, full assessments can be given if multiple views are obtained.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Funding Sources
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Resveratrol Supplementation in 45 Horses With Hock Lameness: A Randomized, Blinded, Placebo-Controlled Clinical Trial

Ashlee E. Watts, DVM, PhD, DACVS*; Robin Dabareiner, DVM, PhD, DACVS; Chad Marsh, DVM, MS, DACVS; G. Kent Carter, DVM, DACVIM; and Kevin J. Cummings, DVM, PhD

This is the first randomized, blinded, and placebo-controlled study to document reduced lameness after administration of a joint supplement in horses with naturally occurring tarsal-associated lameness. Authors' addresses: Department of Large Animal Clinical Sciences (Watts, Dabareiner*, Marsh, Carter), Department of Veterinary Integrative Biosciences (Cummings), College of Veterinary Medicine & Biomedical Sciences, Texas A&M University, College Station, TX 77843; e-mail: awatts@cvm.tamu.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Joint supplements have been used for many years in horses. Our objective was to determine the effect of resveratrol supplementation in horses with lameness originating from the hock.

2. Materials and Methods
This was a randomized, blinded, placebo-controlled clinical trial in 45 client-owned horses. Horses with distal tarsal joint–associated lameness were included. All horses received triamcinolone injection to both centrodistal and tarsometatarsal joints. Placebo or resveratrol supplement was fed twice daily by owners until the recheck examination at 4 months. Lameness was recorded at the enrollment and recheck (4 mo) examinations. Rider response to a questionnaire was recorded at 2 and 4 months post-enrollment. The primary outcomes were performance status as determined by rider opinion (better, worse, same) and change in lameness from the enrollment examination.

3. Results
Complete data were obtained on 41 horses (resveratrol, n = 21; placebo, n = 20). Rider-reported success (rider score of better) was significantly higher among the resveratrol group at follow-up (2 mo, 95% resveratrol vs 70% placebo; 4 mo, 86% resveratrol vs 50% placebo). Objective lameness at the exit examination (A1A2 ratio) was significantly improved in the resveratrol group compared with the placebo group.

4. Discussion
Oral supplementation of resveratrol compared with placebo resulted in reduced lameness 4 months after intra-articular administration of triamcinolone to
the distal tarsal joints in horses with tarsal-associated lameness.

Acknowledgments
This study was approved by the University’s Animal Care and Use Committee as well as the University’s Clinical Research Review Committee.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Funding for this study was provided by Equithrive. They were not involved in trial design, data collection and analysis, or in the decision to publish or in manuscript/abstract preparation or approval.

Footnotes
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bDr. Marsh’s current address is ESMS, 2991 Interstate 20 Frontage Road, Weatherford, TX 76087.
How to Evaluate a Saddle as a Potential Cause of Back Pain

Scott W. Anderson, DVM

A poorly fitting saddle can affect a horse’s performance and behavior. Evaluation of a saddle and back provides valuable information helping determine whether the saddle is a contributing source of back pain. Author’s address: Woodside Equine Clinic, PO Drawer 989, Ashland, VA 23005; e-mail: sanderson@woodsideequineclinic.com. © 2016 AAEP.

1. Introduction
The saddle is the interface between the rider and horse. This connection should allow the rider to feel and communicate with the horse and the horse to move in a well-balanced way without inhibiting thoracolumbar, scapular, or cervical movement. The saddle must fit well for a horse to advance in its training and become progressively stronger.

Numerous studies have been published showing the effects of saddles on the horse. Ill-fitting saddles have been shown to negatively affect the horse’s quality of gait, back movement, muscular development, and performance, and cause thoracolumbar pain.1,2 Studies have been performed evaluating the amount of pressure created by ill-fitting saddles necessary to cause back soreness.3 As practitioners we have all witnessed poor performance or behavior due to an ill-fitting saddle and observed focal swelling or palpated areas of soreness under the saddle.

The purpose of this paper is to demonstrate a static examination of the saddle and horse to help the practitioner determine whether a saddle is causing back pain. Although the examination will help to determine whether a saddle fits, proper saddle fittings are a more complicated matter. A complete saddle fitting should include observation of the rider on the horse in motion as well. There are many opinions as to what is the most objective way to determine saddle fit. The literature advocates the use of saddle pressure measurement devices but other research has also included optical motion cameras, force-measuring treadmills, inertial measurement of body motion,4 and electromyography (EMG).5

2. Materials and Methods
The initial examination is performed with the horse standing squarely and without a saddle pad. The saddle is placed caudal to the scapulae so that the caudal excursion of the scapula during front leg extension would not interfere with the saddle. This is typically 3–5 cm caudal to the scapulae.

Level
A saddle is level when the deepest point of the seat is horizontal with the ground. The deepest point is approximately the center of the saddle from cranial to caudal (Fig. 1). Level is not necessarily when the pommel and the cantle are at the same height.

A tree that is too narrow for the wither will cause an uphill appearance of the saddle (Fig. 2). Less
commonly, a very prominent wither or lordosis can cause a similar appearance. An uphill saddle will cause more of the rider’s weight to be distributed in the caudal third of the saddle, thus leading to soreness in this area.

Conversely, a saddle with too wide of a tree will tilt forward causing a downhill appearance (Fig. 3). In this orientation the saddle is not supportive of the rider’s forward motion. The result is higher pressure and discomfort at the base of the wither and often on midline over the spinous processes. A wide tree can also cause the points of the tree or the flap to apply pressure to the caudal aspect of the scapulae. This can lead to restriction of the scapular motion and decreased forelimb protraction.

Caudal to Cranial Rocking
The cranial to caudal stability of the saddle can be assessed by placing one hand on the pommel and one on the cantle and applying alternating pressure. Ideally, there should be minimal movement. If the saddle rocks forward and back it is a sign the tree is too wide or the panels are too curved. If this is the case there is usually a lack of contact at the rear of the saddle.

When the tree is too wide the rocking action creates a pivot point that is typically on the midline and extends laterally to the base of the wither. This area often demonstrates swelling and sensitivity.

If the panels are too curved, the rocking action causes pressure in the mid-to-lower thoracic area under the center third of the saddle. This usually causes soreness on either side of midline where the panels contact.

Pommel Clearance
There should be clearance between the wither and the pommel. The amount of clearance varies with the type of saddle and conformation of the wither. The clearance can be examined with the rider’s weight in the saddle as well as on static examination.

Contact of the pommel with the wither can cause signs of mild bruising to ulceration of the dermis depending on the degree of pressure. Contact between the tree and the wither is usually caused by a tree that is too wide.

Contact Between the Wither and the Tree
The contact between the wither and the tree should be evaluated on both sides of the horse. Ideally, the contact should be over a broad surface area without areas of focal pressure. The contact can be assessed by placing a hand between the wither and tree to determine whether the contact is consistent (Fig. 4). There is typically 4–5 inches of contact from dorsal to ventral. If the majority of contact is in a focal area near the dorsal aspect of the wither, the tree is typically too wide. If the greatest contact is lower on the tree, it is too narrow (Fig. 5). It is important to extend the hand caudally to evaluate the contact in the caudal tree.

Contact Between the Panel and the Back
Examining the contact between the panel and the horse’s back is important in determining whether there are areas of excessive pressure. The procedure is performed on both sides of the horse. On the left side of the horse, the left hand places pressure on a central point on the top of the saddle and
the right hand is placed between the panel and the horse’s back. The right hand starts cranially at the level of the tree and moves caudally (Fig. 6). The contact of the panel with the horse should be over a broad surface area with even pressure from wither to cantle. This should be repeated several times to obtain a consistent evaluation.

The contact between the panel and the back is an assessment that becomes easier with experience. The goal is to notice specific pressure points, bulges in the panel, and areas that lack contact (Table 1). When performed properly there should be good correlation with computerized pressure sensors.

Examination of the Back Under the Saddle

If the horse has been ridden regularly and recently with the saddle being evaluated, examination of the back for patterns of pain, swelling, rubbed hair, and coat and skin abnormalities is helpful. Saddle problems found in the initial part of the evaluation will correlate with these findings.

Palpation of the back under the area contacted by the saddle should be performed with firm digital palpation or with an instrument such as a needle cap. A typical painful response secondary to pressure points from a saddle is to move away from the pressure and/or show excessive muscle contraction. The responses vary with the sensitivity of the horse. The pressure applied may need to be varied accordingly. As with any examination, the more of them you perform, the easier interpretation becomes.

The examination starts with palpation of the dorsal and caudal aspects of the scapula. Pressure is applied to the midline over the dorsal spinous processes and is best done with digital pressure rather than with a firm object. Palpation of the area un-
underlying the saddle can be performed by applying pressure in a vertical or grid pattern looking for more reactive areas.

Soreness under the saddle can be hard to interpret when there is generalized discomfort. Pain under the saddle can potentially be caused by problems other than an ill-fitting saddle. Ideally, the examiner is looking for focal patterns of soreness, often bilaterally, that correlate with saddle problems found earlier in the examination (Figs. 7–11).

3. Results
Saddle evaluation has proven beneficial to the practice as an additional service we can offer, contributes valuable information when evaluating sore backs, and can help the client with decision making with regard to their saddle.

We are often asked to evaluate saddles when a horse exhibits signs of not wanting to be tacked, cold back, behavioral problems when ridden, obvious back pain when ridden or groomed, atrophy of back muscles, swelling under the saddle, or hair follicle damage.

We performed fifty saddle examinations in 2015. The horses examined were show hunters and jumpers. The findings of the examination are summa-

### Table 1. Evaluation of Pressure Points

<table>
<thead>
<tr>
<th>Palpation</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pressure points in the ventral and lateral aspect of the tree and under the caudal third of the saddle with no contact in the middle of the panel</td>
<td>Narrow tree with bridging</td>
</tr>
<tr>
<td>Pressure points in the dorsal aspect of the tree and the base of the wither with lack of contact under the caudal aspect of the panel</td>
<td>Wide tree</td>
</tr>
<tr>
<td>Pressure points along the middle third of the panel</td>
<td>Excessively curved panel</td>
</tr>
<tr>
<td>Focal bulges in panel</td>
<td>Saddle needs re flocking or examination by saddle fitter</td>
</tr>
</tbody>
</table>

Fig. 7. Soreness on the dorsal aspect of the cartilage of the scapula (indicated in red) can be caused by a saddle placed too far cranially.

Fig. 8. Soreness on the caudodorsal aspect of the scapula is caused by too wide of a tree or the flap interfering with the scapula.

Fig. 9. A saddle with a wide tree will rock forward and back with a pivot point at the base of the wither. The cranial aspect of the saddle slides forward, thus applying pressure to the caudodorsal aspect of the scapula. The caudal aspect of the saddle rocks up and down causing soreness.

Fig. 10. A saddle with a narrow tree will bridge applying pressure on the lateral aspect of the wither and on the panel under the caudal third of the saddle resulting in soreness in these areas.
ized in Table 2. The second column refers to saddles without the negative qualities described above.

Twenty of the horses examined by palpation exhibited soreness related to ill-fitting saddles. Five of these horses exhibited signs such as aversion to being tacked, dropping when mounted, and misbehaving when ridden due to back pain. One horse was obviously lame due to pressure of the saddle on the caudal aspect of the scapulae. When the saddle was removed the lameness was no longer present.

4. Discussion

When evaluating a horse with a sore back it is important to realize there is often more than one area of discomfort or cause of pain. A poorly fitting saddle can be the primary cause or an additional source of soreness. An examination of the whole back, lameness evaluation, and other diagnostics are often necessary to completely assess a sore back.

A complete saddle fitting includes additional steps beyond the evaluation described in this paper. Ideally, this should be performed by a professional saddle fitter or a veterinarian with a great deal of experience in saddle fitting. There are many nuances involved in appraising whether a horse and rider will be comfortable and perform well with a saddle.

There are important topics involving saddle fit beyond the scope of this paper. Saddle pads can effect whether a saddle fits well or poorly. If a saddle fits well minimal padding is necessary. Excessive padding applied to a proper fitting saddle can be a source of pain. Padding can improve the fit of a saddle when minor changes are needed but will not improve a poorly fitting saddle. The materials they are composed of can also improve the load on a horse’s back.

The evaluation of a saddle may need to be performed periodically. Saddles change with use, especially if employed on multiple horses. If the saddle is wool flocked it will need to be reflocked with use. A saddle that fits a horse well at one time can eventually fit poorly due to changing back conformation with age or atrophy. As a horse’s musculature develops with age and exercise, the saddle may need to change.

The saddle has a great effect on the comfort and performance of the horse. Evaluation of the saddle allows the examiner to insure the saddle is not a source of pain.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

Serum and Synovial Fluid Serum Amyloid A in Equine Models of Synovitis and Septic Arthritis

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Serum and synovial fluid serum amyloid A may be useful in diagnosing septic arthritis in horses. Authors’ addresses: Department of Large Animal Clinical Sciences (Ludwig, Wiese, Graham, Tyler, Settlage, Dahlgren), and Laboratory for Study Design and Statistical Analysis (Were), Virginia-Maryland College of Veterinary Medicine, Blacksburg, VA 24061; Department of Dairy Science, College of Agriculture and Life Sciences, Virginia Tech, Blacksburg, VA 24061 (Petersson-Wolfe, Kanevsky-Mullarky); e-mail: lad11@vt.edu. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Clinical findings and synovial fluid cytology are insufficient to confirm a diagnosis of septic arthritis in some cases. The objective of this study was to investigate the serum and synovial fluid, serum amyloid A (SAA) response in equine models of synovitis and septic arthritis and to compare handheld and immunoturbidometric assays for SAA quantification. We hypothesized that SAA in serum and synovial fluid from horses with septic arthritis would be significantly elevated compared with synovitis and there would be good agreement between SAA assays.

2. Materials and Methods
Synovitis and septic arthritis were induced in nine adult horses using lipopolysaccharide and S. aureus, respectively. Serum and synovial fluid were collected serially and synovial fluid cytologies performed. Serum and synovial fluid SAA were quantified by handheld and immunoturbidometric assays. Cytologic and SAA data were compared within and between models, and SAA assays were compared using continuous data and category by category analysis.

3. Results
Synovial fluid total nucleated cell count (TNCC) and total protein (TP) increased significantly following model induction. Serum and synovial fluid SAA remained normal in horses with synovitis and increased significantly in horses with septic arthritis. There was good category-by-category agreement between SAA assays (weighted $κ = 0.824$). Agreement was 98% when SAA values were low ($<50 \mu g/mL$).

4. Discussion
Elevation of serum or synovial fluid SAA above normal values may suggest synovial sepsis given that
synovial inflammation alone did not result in SAA elevations in our models.

**Acknowledgments**

*Declaration of Ethics*

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

*Conflict of Interest*

The Authors declare no conflicts of interest.

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Funded by the Veterinary Memorial Fund, Virginia-Maryland College of Veterinary Medicine and the Virginia Horse Industry Board. StableLab (Epona Biotech Limited) donated a portion of the handheld test kits but had no influence over the study protocol or manuscript.
Measurement of Synovial Fluid L-Lactate Concentration in Horses With or Without Septic Arthritis

Alexander Daniel, BVetMed, MS, DACVS*; and Byron Reid, VMD

Synovial fluid lactate concentration was significantly elevated in horses with septic arthritis; therefore, measurement of synovial lactate may help with early detection of septic arthritis. Authors’ address: Reid and Associates Equine, Loxahatchee, FL 33470; e-mail: adanielvet@gmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Early diagnosis and treatment of septic arthritis is important. Synovial fluid analysis is the best means to establish a diagnosis; however, in some situations results of analyses (total nucleated cell count [TNCC], total protein [TP], color, etc.) can be inconsistent or are not available rapidly (e.g., culture). The goal of this study was to evaluate synovial L-lactate concentrations in horses with naturally occurring septic and nonseptic arthritis using a portable lactate reader.

2. Methods
Adult horses (> 2 y) presenting to a referral hospital in South Florida with potential septic arthritis of one limb were included. Total nucleated cell count, TP (g/dL), and lactate (mmol/L) were recorded and statistical analysis used to evaluate factors associated with lactate. Septic arthritis was confirmed if TNCC was greater than 30,000 × 10⁶ cells/L, TP greater than 4.0 g/dL, and supported by both clinical and cytological findings.

3. Results
All horses with septic arthritis had elevated lactate compared with nonseptic arthritis. Prior joint injection and increased duration of time prior to referral did not cause statistically significant elevations in lactate.

4. Discussion
The lactate reader used in this study is a cost-effective, portable unit that can provide stall-side evaluation of synovial lactate. Based on the results of the current study, the use of synovial lactate seems justified; however, the authors recommend that other synovial analyses (e.g., TNCC, TP) are always performed. Although previous research found that lactate was elevated following intra-articular corticosteroid (methylprednisolone), this was not seen in the current study; however, most horses received a different corticosteroid or a blood-derived product.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Preliminary Study of Risk Factors Associated With Biaxial Proximal Sesamoid Bone Fractures in Thoroughbred Racehorses

Scott E. Palmer, VMD, DABVP*; Hussni O. Mohammed, Vet MB, PhD; and Jon Cheetham, Vet MB, PhD, DACVS

A preliminary screening profile was developed to help identify horses at risk for biaxial proximal sesamoid bone fracture. Authors’ addresses: Department of Population Medicine and Diagnostic Sciences (Palmer, Mohammed), Department of Clinical Sciences (Cheetham), Cornell University College of Veterinary Medicine, Ithaca, NY 14850; e-mail: sepalmer@att.net. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Biaxial proximal sesamoid bone (BPSB) fractures are a common cause of catastrophic injury in Thoroughbred racehorses. This study sought to identify factors that predispose horses to BPSB fracture and to quantify their associated risk.

2. Materials and Methods
A matched case-control study was conducted with 20 cases of BPSB fracture and 40 control horses, randomly selected from the same race. Eighty-two putative risk factors were examined for association with BPSB fracture.

3. Results
Case horses had fewer starts in the second and third years of racing, fewer high-speed furlongs in the final 12 weeks leading up to the incident race, and more weeks of rest in the final 8 weeks prior to the incident race than did controls. Case horses were more likely to drop in race conditions by two classes between the penultimate and incident races.

4. Discussion
This study provides a useful preliminary screening profile to help identify Thoroughbred racehorses at risk for BPSB fracture.

Acknowledgments
The Jockey Club facilitated data collection. The Harry M. Zweig Memorial Fund provided financial support.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Racing Prognosis Associated With Fractures of the Accessory Carpal Bone in Thoroughbred Yearling Racehorse Prospects

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In a population of Thoroughbred yearlings presented at public auction, race performance of yearlings with accessory carpal bone fracture was not significantly reduced compared with unaffected peers. Identification of accessory carpal bone fracture in clinically normal yearlings should not be considered a condemning finding. Authors’ addresses: Equine Medical Center of Ocala, 7107 West Hwy 326, Ocala, FL 34482 (Davern*, Peloso); Equine Medical Associates, PSC, 996 Nandino Blvd, Lexington, KY 40511 (Morehead); Department of Veterinary Clinical Sciences (Hawkins); and Veterinary Administration Department (Moore) Purdue University, West Lafayette, IN 47907; e-mail: alecdavern@gmail.com *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Prepurchase assessment is a professional and legal liability for veterinarians and assessments should be based on objective information when available. Accessory carpal bone (ACB) fracture is occasionally documented on survey radiographs of young Thoroughbreds and no large-scale peer-reviewed report of clinical relevance is currently available. The objective of this study is to determine the affect of ACB fracture identified on survey radiographs of yearling Thoroughbreds on future racing performance using peer controls.

2. Materials and Methods
Radiographs from the yearling sale of Thoroughbreds in Kentucky (2005–2012) were reviewed and race records were evaluated. The ability to start a race at 2 or 3 years of age and number of starts, earnings, and earnings per start were compared.

3. Results
There were no significant differences in the ability to start a race at 2 or 3 years old or any other performance variable between horses with ACB fracture and controls.

4. Discussion
This data indicate that in yearlings without lameness at the walk or outward sign of orthopedic malady, fractures of the ACB are not expected to negatively impact the horse’s ability to start a race at 2 or 3 years of age. The retrospective nature of study prohibits historical investigation that may reveal previous lameness or treatments.
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Declaration of Ethics

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Overview of Options for Equine Infectious Disease Prevention and Control

Josie L. Traub-Dargatz DVM, MS, DACVIM

Infectious disease can impact horses in any sector of the industry. Outbreaks of disease can impact the use of horses, leading to costs for disease treatment and containment as well as income loss for those who make a living in the equine industry. These proceedings provide background information on infection-control concepts and summarize resources available to stakeholders in the equine industry as they fulfill their role in protecting equine health. Author’s address: Colorado State University, College of Veterinary Medicine and Biomedical Sciences, and Equine Commodity Specialist for USDA-APHIS-VS, Center for Epidemiology and Animal Health, Fort Collins, CO 80523; e-mail: josie.traub-dargatz@colostate.edu. © 2016 AAEP.

1. Introduction
Infectious diseases include those caused by various pathogens, such as viruses, bacteria, and parasites. Not all infectious diseases are contagious. For example, West Nile virus (WNV) causes an infection in horses but is not spread from horse to horse (infectious but not contagious). Instead, horses are infected with WNV by the bite of a mosquito carrying the virus. Infectious diseases can endanger the wellbeing of horses and the people who work with them, at least for some diseases such as rabies and salmonellosis.

Equine infectious diseases can have devastating financial and emotional effects on horse owners and those who make a living in the equine industry. Depending on the disease situation, effects can include:

- Temporary or permanent loss of use
- Death of affected horses
- Restrictions on the movement of diseased and exposed horses
- Costs associated with treating affected horses
- Associated costs of implementing biosecurity procedures or other preventive measures.

2. Infection Control
An infection-control plan should take into account the level of disease risk, the risk aversion of stakeholders and, for some diseases, the standards set by rules and regulations of the State Animal Health Official, United States Department of Agriculture - Animal Plant Health Inspection Service - Veterinary Services (USDA-APHIS-VS), or officials hosting an equine event.

Every equine facility or equine population is unique, and even though overarching general principles for infection control apply across all facilities and various equine populations, each equine operation should tailor a biosecurity program specifically designed for their equine population or facility. Biosecurity practices for controlling infection are only as effective as the weakest link in their implementation. For example, if nine of 10 equine care
providers wash their hands when moving between segregated horses, the one provider who does not can introduce or spread pathogens, even though the other nine did the right thing.

In the past 20 years, outbreaks of equine infectious diseases have had major effect on the health of individual horses and the equine industry. These outbreaks led to the development of strategies for preventing some infectious disease outbreaks and for optimizing containment efforts for diseases that cannot be prevented. Options for controlling infectious diseases can be placed into two broad categories: actions that reduce the risk of exposing horses to pathogens and actions that optimize resistance to infection or disease. Advances have occurred in both categories during the last 20 years.

3. Personal Interest in Infectious Disease

In 1996, an outbreak of *Salmonella* Infantis at Colorado State University’s Veterinary Teaching Hospital’s (CSU-VTH) Large Animal Clinic1 led to my interest in biosecurity. Although I had an interest in the clinical and research aspects of infectious diseases before this outbreak, I had never before used the terms “biosecurity” or “critical control points,” nor had I recognized that the “devil was in the details” when mitigating or preventing a contagious disease outbreak.

Our efforts to resolve this outbreak provided my colleagues and me at CSU-VTH with many valuable insights. Those of us involved in the outbreak mitigation published manuscripts that included the many lessons learned; subsequently, the University hired a director of biosecurity. We continued to conduct multiple research projects related to infection control to develop a science-based biosecurity standard operating plan for CSU-VTH (available at http://csu-cvmbs.colostate.edu/Documents/biosecurity-sop.pdf).

4. Options for Infection Control

Administering vaccines optimizes resistance to infection for at-risk equine. Recently, new licensed vaccines have been developed for equine diseases for which there was no vaccine available. For example, WNV was first recognized in the United States in 1999. By summer 2001, a conditionally licensed vaccine was available for immunizing U.S. equids against WNV. Subsequently, new vaccine technology that had never been used in the production of equine vaccines was implemented to develop vaccine products for controlling WNV in equine. Examples of other relatively new vaccines for equine include vaccines for controlling rhinitis virus, pigeon fever, and leptospirosis.

Equine veterinary practitioners are expected to play a pivotal role in preventing, investigating, and mitigating infectious-disease outbreaks. Today, equine veterinarians face sophisticated, often daunting challenges. To effectively prepare and plan for a disease outbreak, veterinarians must have a good understanding of modern resources and strategies. In addition, veterinarians must have the trust and financial support of owners, farm managers, and event organizers.

Based on its scope, effect on business continuity, and the effect it had on infected horses, the multi-state outbreak of equine herpesvirus myeloencephalopathy (EHM) in 2011 was a game changer for the equine industry. Today, the equine industry seems to be interested in investing more time and money to develop comprehensive plans that address some controllable equine diseases.

5. Role of Veterinary Practitioners in Infection Control

An equine practitioner is likely the first person an equine owner calls when a horse is sick, which usually puts the practitioner first on site and creates an opportunity for him or her to play a role in the diagnosis and containment of a contagious disease. Equine veterinarians who work at equine events or sales facilities could also play a role in developing specific protocols that reduce the risk of disease introduction. In the case of a potential disease outbreak, the initial actions of the equine practitioner can have a major effect in preventing the spread of the disease. If faced with a potential outbreak, it is important that the equine practitioner determine whether he or she has the authority to direct the control of the outbreak and whether he or she is obligated to report the situation to veterinary regulators. Depending on the scope and type of outbreak, a practitioner may want to consider involving a team of people with expertise in areas such as diagnostic laboratory testing, epidemiology, biosecurity, and pathology.

Equine practitioners have a role in developing detailed vaccination plans for their clients’ horses. For example, a plan might call for the veterinarian to personally administer vaccines to their equine patients, sell vaccines for clients to administer, or advise clients on the most appropriate vaccines to purchase, thus leaving the administration of vaccines to the client. Many practitioners have limited their role in infection control to the oversight of vaccinations, feeling that their expertise in developing biosecurity protocols cannot be marketed. However, now could be an opportune time for veterinarians to expand their roles in reducing the risk of disease exposure for their equine patients.

Implementing biosecurity methods that reduce the risk of exposing equine to infectious disease agents is more challenging than simply immunizing equine. Reducing the risk of exposure can fall into several categories and is dependent on the disease agent, the signalment, the use and location of the horses, and environmental factors. It is likely impossible to eliminate all exposure risks, especially among horses that commingle with horses from different facilities or on operations where outside...
horses are introduced to the resident equine population.

Recent outbreaks have created more interest in biosecurity methods from equine owners and equine event organizers. Thus, equine practitioners could advise equine owners on the methods of infection control beyond vaccination, such as those that reduce the risk of exposing equine to infectious disease agents at their home operation or while off the home operation. In addition, by developing a marketing strategy for infection control beyond vaccination, veterinarians could expand their practice offerings and improve the health of their equine patients.

6. Information Resources for Equine Veterinarians

There is an ever-expanding library of equine textbooks on biosecurity and specific equine infectious diseases. For example, the second edition of Equine Infectious Diseases has an entire chapter on biosecurity, 14 chapters on viral diseases, 19 on bacterial and rickettsial diseases, eight on fungal diseases, and seven on parasitic diseases.

The American Association of Equine Practitioners (AAEP) developed guidelines for vaccinating horses. These guidelines provide exposure-risk categories as well as specific recommendations for vaccinating various categories of horses (e.g., foals, broodmares, and other adult horses; available at www.aaep.org). In addition, the AAEP has guidelines for infection control at equine events and for venereal disease. Infection-control guidelines at equine events provide equine practitioners with an action plan when faced with an equine infectious-disease outbreak and provide details regarding the clinical and laboratory diagnostic aspects of selected equine diseases. The guidelines also include disease-prevention planning. The AAEP regularly reviews these guidelines. In addition, articles such as EquiManagement’s “Teaching Biosecurity at Shows & at Home” provide tips about educating clients and facility managers on implementing biosecurity practices before a disease problem occurs.

The neurologic form of equine herpesvirus is of concern to equine owners, equine trainers, event organizers, and state animal health officials. The U.S. Animal Health Association’s (USHA) Infectious Diseases of Horses Committee developed a guideline for managing EHM outbreaks (available at http://www.usaha.org/). Although this guideline was primarily directed at state animal health officials, any veterinarian involved in the mitigation of an EHM outbreak will find the information of use. This guideline has multiple sections including 1) diagnostic testing, 2) quarantine placement, 3) quarantine release, 4) investigation and biosecurity measures, 5) incident communication, and 6) vaccination.

7. Information for Equine Owners

The USDA-APHIS-VS has recently updated an information sheet titled, “Biosecurity Tips for Equine Owners,” which gives general guidance on infection control. The sheet emphasizes key infection-control points that equine owners should be aware of and can be found at http://www.aphis.usda.gov/animal-health/equine-health.

An equine biosecurity risk calculator is available from Equine Guelph (University of Guelph). As its name implies, this calculator enables equine owners and farm managers to assess the risk of introducing disease to their facility and provides educational materials related to controlling equine infectious diseases. The calculator is available at http://www.equineguelph.ca/Tools/biosecurity.php. Other educational materials on this Web site include biosecurity information presented via a whiteboard scribble video and interviews with equine trainers regarding their approach to infection control.

The “Equine Biosecurity Principles and Best Practices Guide,” was developed by the Alberta Veterinary Medical Association and the Alberta Equestrian Federation as a way to interactively educate horse owners while encouraging discussions with a veterinarian regarding biosecurity on their facility. This tool is available at http://alberta equestrian.com/wp-content/uploads/2015/03/2014_biosecurity_book.pdf.

In addition to Web sites, other media have recently featured stories about infection control, vaccination, biosecurity, and specific equine infectious diseases. Many of these stories emphasize the importance of equine owners in working with their veterinarian, because he or she is most familiar with the owner’s horses and the specifics of the operation. This familiarity puts their veterinarian in the best position to develop a tailored vaccination and biosecurity plan.

8. Information for Equine Events or Venues


The California Department of Food and Agriculture developed a biosecurity toolkit for equine events. This toolkit has two main themes: ways to reduce the risk of introducing disease to an equine event, and reducing the risk of spreading pathogens if an infectious disease occurs at an equine event. In addition, the toolkit’s appendices includes materials that support the implementation of various practices covered in the toolkit. The toolkit is available at https://www.cdfa.ca.gov/ahfss/Animal_Health/Equine_Biosecurity.html.

The Colorado Department of Agriculture’s State Veterinarian’s office has met with several equine event organizers to review a template for a business
continuity plan for use at equine events. During a presentation at the USAHA’s Infectious Diseases of Horses Committee, Dr. Carl Heckendorf presented highlights of his experiences working on biosecurity practices with equine event planners: https://www.colorado.gov/pacific/sites/default/files/EHV-1%20Biosecurity%20Guidance%20for%20Equine%20Event%20Organizers_0.pdf.

The Horse magazine has featured a biosecurity tip-of-the-month on their Web site based on a biosecurity calendar developed by the California Department of Agriculture. Each month an important equine biosecurity principle was highlighted.

9. Implementing of Biosecurity Measures
Identifying facilities that can be used for isolation, whether to prevent disease introduction or to limit the spread of disease, is an important part of biosecurity. Implementing effective isolation measures requires predetermined protocols and supplies. However, during some of the most important high-risk situations there is often no provision for isolation facilities nor the associated actions necessary to isolate a contagious disease in a timely and effective manner. Here are some key steps to take when responding to a suspected infectious disease situation:

1. Do no harm. Do not rush into a stall until you have a plan.
2. Take biosecurity precautions to avoid worsening the situation.
3. Communicate your findings to the horse owner and event organizer (if the horse is at an event when it becomes sick). At the same time, take appropriate actions to restrict the spread of disease. Initial biosecurity measures should be aimed at controlling a possible outbreak until you have evidence confirming that no disease is present.

Veterinarians should carry a biosecurity kit in their vehicle with materials designed to reduce the likelihood of spreading contamination from horse to horse. The biosecurity kit should contain examination gloves (a pair for each horse to be examined), coveralls dedicated to each horse’s examination or to a group of animals of equal disease status, a covering for the upper body impervious to secretions such as nasal discharge, plastic footwear covers, and some kind of head covering. Once barrier precautions are removed, a disinfectant solution should be applied to footwear soles after the plastic covers are removed, and a supply of hand sanitizer or access to soap and water should be available.

Whether at a farm or an event center, it is important to ensure that there are adequate supplies on hand to implement biosecurity measures. Supplies include disinfectant, stall-cleaning equipment, feeding equipment and grooming supplies that can be dedicated to caring for isolated horses, barrier precaution supplies for personnel caring for isolated horses, and enough signage for 1–2 days.

To ensure that effective disease-control practices are implemented, veterinarians should have a conversation with farm owners and event organizers about how they plan to respond to a contagious-disease situation. For example, a plan that calls for isolating confirmed contagious-disease cases while still caring for the animals can expedite the control of disease spread. The Equine Biosecurity Toolkit for Equine Events has information about how to set up a temporary isolation area, implement movement restrictions within a facility, use barrier precautions, and determine the likely level of exposure.

Veterinarians that work for an equine event are in an ideal position to implement a plan to reduce the risk of disease introduction, should a contagious disease occur at the event. If equine practitioners are in charge of biosecurity during an outbreak situation, it is important that they personally observe how and if people are following biosecurity recommendations. If necessary, veterinarians should physically show event personnel exactly how to follow isolation and similar protocols. Do not assume that oral or signage instructions will be obvious. It is also important that veterinarians set the standard through their own behavior, and that they never take shortcuts when performing biosecurity protocols.

Veterinary textbooks have entire chapters about biosecurity, which can serve as a resource for equine practitioners as they serve their clients.2

10. Role of Veterinarian in Making a Diagnosis
History and physical findings should be considered when assessing equine infectious-disease status. These findings should dictate the required diagnostic testing. Collecting diagnostic samples, selecting diagnostic tests, and interpreting test results will be described in detail in other parts of this in-depth session. In addition, risk aversion and what is at stake are important factors to consider when making the decision to run tests. A key take-home message is to not run tests without first determining how you will use and communicate the results. Optimal sample collection and shipping are as important as testing. Identify laboratories and their respective testing capabilities before you need them. Some laboratories are able to offer a wide array of diagnostic testing by forwarding received samples to other laboratories. In time-sensitive situations, diagnostic test results can be expedited by submitting samples directly to the laboratory performing the test. Laboratory personnel can help you determine the most appropriate samples to collect, discuss available test formats, designate how you want to receive the results, and establish a likely timeframe for receiving results. It does make a difference which disease agent is causing an outbreak; for
example, a response to an influenza outbreak will be different than a response to an EHM outbreak. Thus, performing diagnostic testing combined with physical findings are critical in developing the most effective control strategies and are also important in providing communication about the outbreak. The AAEP “Guidelines for Managing Infectious Disease Outbreaks” can assist equine practitioners to develop disease-specific recommendations. These guidelines can be found at http://aaep.org/info/guidelines-50.

Certain suspect or confirmed diseases are reportable to state animal health officials and/or to USDA-APHIS-VS. It is important that veterinarians know what their reporting responsibilities are in their state and act accordingly. In this in-depth session, we will discuss how state animal health officials interact with USDA-APHIS-VS to respond to equine infectious disease situations. When in doubt about infectious diseases, equine practitioners should contact their state animal health official to determine the steps to take next.

11. Role of Veterinarians in Communication

Effective communication is imperative for controlling an outbreak response and for ensuring the confidence of managers, owners, and the public. Effective communication can be as simple as talking to a manager/owner on a daily basis, posting news releases around major show grounds, and keeping the media informed. Training on how best to interact with media is advisable if an equine practitioner is going to act as a spokesperson for an equine event or farm. The important thing is to define the message and determine how to get it across in an unambiguous way. It is also important to stay focused on the facts, remain professional, and indicate what steps are being taken to deal with the incident at hand. Never announce a disaster until you know what steps are being taken to deal with the situation.

Daily updates—even if no change in the situation has occurred—help to keep concerned parties up to date and establish confidence in the person or entity providing the updates. However, do not make a prediction as to the final outcome of a disease outbreak, even if your experience would allow you to do so. It is often best to plan for a worse-case scenario until the outbreak is under control and going to stay that way.

12. Options for Veterinarians in Marketing and Implementing an Infection-Control Program

A very important first step in marketing an infection-control program is for the veterinarian to set a good hygiene example while at an equine operation or event. Veterinarians should practice good hand hygiene while working between groups of horses, and wear clean outerwear and footwear when moving between segregated groups of horses on a single operation or when moving between operations. Some farms may require veterinarians to sanitize their footwear, and some might offer outerwear dedicated for use on their operation. These requests should be readily accepted by veterinarians. In addition, Veterinarians should always use clean equipment and have their vehicles cleaned regularly. Contaminated steering wheels, handles on veterinary boxes, and vehicle floor mats can be vectors for disease spread.

To help sell their management services, equine veterinarians should educate current and potential clients about the effectiveness of their services and establish marketing strategies by illustrating their potential value. Equine veterinarians can provide management programs designed to prevent and control infectious diseases. Boarding farms, training facilities, veterinary practices, equine event facilities, event organizers, even small private horse farms can benefit from these programs. An article on how best to educate clients and facility managers is available in a special issue of “EquiManagement.”

In a recent survey of the horse-competition industry, 80–90% of respondents indicated that they had used the Internet in the previous 6 months for horse care information; however, the Internet was not the preferred source of information. The top three preferred sources of information regarding horse health care were veterinarians (93% of respondents), farriers (77%) and trainers (68%).

By providing diagnosis and treatment services, veterinarians can tailor prevention and intervention plans for a farm’s or an event’s population of horses. Veterinarians can do this by recommending traditional vaccination- and parasite-control programs and products, and by advising their clients on other aspects of infection control (e.g., early detection of disease, early intervention if an outbreak occurs, reduction of exposure risk, and other means of enhancing specific and nonspecific resistance [immunity] to disease).

Veterinarians should consider providing services for the following:

- Mitigating an ongoing infectious disease situation (outbreak or endemic disease) in horses on the facility
- Managing an imminent threat of infectious disease, while maintaining some level of business continuity
- Facilitating forward planning with the goal of
  - Ensuring the well-being of horses
  - Improving owner/trainer/manager satisfaction
  - Maintaining business continuity (quarantines will cause loss of business continuity)
  - Enabling competitive advantage (businesses with programs become the standard to which other businesses compare themselves)
  - Reducing a facility’s risk of liability.
Educating clients about the potential ramifications of an infectious disease outbreak can be an effective marketing tool. Ramifications can range from the suffering and loss of affected animals to facility-wide effects due to disease or quarantine. Making these points with decision makers can motivate them to write well-designed disease-prevention programs.

Certain pathogens can remain in horses even after they recover. These persistent infections can force restrictions on how the affected horses can be used. For example, horses that persistently shed *Salmonella* sp. or *Streptococcus equi equi* might have to remain separated from other horses and/or might be prohibited from boarding facilities, until shedding of these pathogens has ceased.

An infection-control program’s components depend on the equine population and type facility for which it was designed. Specifically, it is based on the lifestyle of the horses. For example, a control program for horses that live a relatively isolated existence on a remote ranch will be different than one for horses that regularly travel to events.

Certainly, it is important to include vaccination as a part of an infection-control program, but clients should be informed that administering a vaccine does not prevent all infections. In other words, simply vaccinating does not make for a comprehensive infectious-disease control program.

Ideally, veterinarians should conduct an evaluation by walking through the facility with the owner/managers. This walkthrough—along with inquiries about the demographics of the horse population, traffic flow on the operation, and existing equine health management—enables the veterinarians to identify the many ways horses could be exposed to infectious disease agents. Potential exposure risks include the following:

- Other horses (those that frequent equine events, new arrivals, visiting horses).
- Other types of animals (wild animals, other livestock, birds, and rodents).
- Environmental factors (feed, water, bedding, stabling, trailers, insects, ticks, airborne).
- People and objects traveling on/with them (horse caretakers, stall cleaners, veterinarians, farriers, and their clothing, equipment, footwear, and vehicles, etc.).
- During the walkthrough, veterinarians should view horses as they move through the facility and pay special attention to the protocols for arrival and departure areas, stabling, and water and feed sources. Make note of any difference between what owners/managers have described as their infection-control techniques and what actually occurs on the operation. For instance, when an event organizer cites a facility as having separate pens for horses, they might be thinking of separation that prevents injury, not separation for infection prevention. Yes, the horses might be separated and thus unable to injure one another, but they still share an air space and/or can touch noses through gaps in fencing, share a water source and, thus, spread disease.
- Following human traffic patterns during an on-site evaluation is also important. For example, during a disease outbreak at a racing facility, trainers from several barns congregated for coffee in a quarantined barn after morning workouts, not realizing that movement restrictions pertained to them as well as to the horses.
- In another example, a facility had quarantined all equine other than racetrack ponies (mounts used to lead racehorses to the track) and were letting the ponies come and go from the quarantined barns. In this case, apparently trainers were unaware that the movement restrictions applied to the ponies and to the racehorses. These examples illustrate that addressing the details of equine and human movement is very important when designing a control program.
- It is also important that veterinarians interview the people who provide horses with hands-on care (not just the facility manager) about their care practices. These interviews are the only way to obtain details related to their processes for horse care and, thus, very important in both outbreak mitigation and plan development.
- During a walkthrough, veterinarians should create a report based on a predetermined checklist. In addition, photographs should be taken illustrating detailed recommendations specific to each operation. After completion, veterinarians should review the report with the facility manager or equine owner and work on a timeline for implementing agreed-upon procedures. Consider dividing recommendations into categories. For example, separate recommendations that can be done immediately from actions that take longer to implement. While reviewing short-term and long-term recommendations with the manager or owner, emphasize that he or she must make their own cost-benefit decisions, based on risk-aversion vs costs of implementing the proposed recommendations. Keep in mind, treatments cost money, take time, and can cause distress in horses. For example, some horses develop behavior problems when given oral medications or injections, which can undo months of training. In addition, adverse reactions to drugs, such as antibiotics associated with diarrhea, can promote antibiotic resistance in pathogens.
- It is also important that veterinarians be prepared for an infectious disease outbreak. For example, if a veterinarian happened to be on a call 30 miles from his or her office when asked to investigate a potential case of infectious/conta-
gious disease, they should already be equipped with the necessary tools to implement barrier precautions, such as disposable outerwear. As mentioned previously, keeping a biosecurity kit in the practice vehicle is a good idea.

- Despite best-laid plans for high-risk groups of horses, infectious/contagious disease will occur; however, with adequate preplanning and an action plan, risks and response times can be reduced.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References
Equine Infectious Gastrointestinal Disease—Approach for the First Responder

J. Scott Weese, DVM, DVSc, DACVIM

1. Introduction
Infectious gastrointestinal (GI) disease is a common and potentially devastating problem in horses. Most commonly manifested as diarrhea with varying degrees of systemic illness, and prone to complications such as laminitis and venous thrombosis, it can be frustrating to manage because of the myriad potential causes, difficulties in making a definitive diagnosis, difficulties even determining whether an infectious cause is present, and limited availability of objective information about optimal management and preventive practices.

The incidence of infectious GI disease is not well understood. This is largely because of a lack of adequate study, but is confounded by difficulties defining and diagnosing infectious GI disease and a lack of centralized reporting of data on equine infectious GI disease. Even when diagnoses are made, most causes of enteric disease are not reportable to veterinary regulatory authorities and therefore, there is little or no compilation of case information. Collection of data from laboratories about specific pathogens identified (e.g., isolation of *Salmonella*) can provide some insight, but even those data are limited because of the small percentage of affected horses that are tested and common problems with test sensitivity. Ultimately, a large percentage of cases (a majority in most regions) are undiagnosed.

The spectrum of disease is variable, ranging from inapparent to rapidly fatal, involving a single horse occurring as sporadic cases to widespread and devastating herd outbreaks. The potential severity of disease (especially adult horses with acute colitis) and the potential for outbreaks that require prompt intervention (e.g., outbreaks in foals, contaminated feed–associated disease) mean that a rapid and effective response can be critical.

2. Etiologies
Important etiologies are outlined in Table 1. This is not an exhaustive list given that some pathogens that are rare or poorly characterized causes of GI disease are not included. It is also almost certain that other viral, parasitic, or bacterial causes of disease exist but have not been identified.

It is important to remember that noninfectious causes of diarrhea and colitis occur. This would include nutritional (foals) causes, toxicities (e.g., acorn, NSAIDs, alfalfa dodder (*Cuscuta campestris*), ionophores) and poor water quality (e.g., excessive sulfate). Antimicrobial drug use–associated disease, whether as a response to therapeutic ad-
ministration of antimicrobials or ingestion of contaminated feed is an important problem in the horse, but whether this is from individual pathogens or a more general state of “dysbiosis” is hard to define. The gut microbiota is a highly complex, diverse, and critically important microbial community. It is increasingly clear that the microbiota composition has great influences on health and disease in horses and other species. Although the focus in equine infectious GI disease has been on individual pathogens (e.g., *Salmonella, Clostridium difficile*), it is likely (if not certain) that changes in the overall microbial community composition can result in disease. Antimicrobial drugs are probably the best defined modifiers of the gut microbiota, but various other factors can presumably also influence the microbiota and development of disease.

3. Farm and Horse History

Investigation of any disease requires a thorough history. When dealing with a suspect GI infectious disease, history pertaining to the affected horse, the farm, recent transport, and/or exposure to outside horses at equine events is required. Important aspects are outlined in Table 2.

<table>
<thead>
<tr>
<th>Pathogen and Transmission/Source</th>
<th>Distribution/Season</th>
<th>Outbreaks</th>
<th>Common Diagnostic Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Salmonella</em></td>
<td>More common in southern/warmer regions but endemic.</td>
<td>Numerous Farms and in equine hospitals</td>
<td>Culture, PCR</td>
</tr>
<tr>
<td><em>Clostridium difficile</em></td>
<td>No clear seasonality. Anecdotal differences between some regions but no clear patterns</td>
<td>Mainly outbreaks in foals on breeding farms</td>
<td>Culture + detection of toxin genes, Fecal ELISA, PCR</td>
</tr>
<tr>
<td><em>Clostridium perfringens</em></td>
<td>No apparent seasonality.</td>
<td>Rare. Mainly a concern in foals with certain strains</td>
<td>Culture + PCR, or direct PCR targeted specific genes (e.g., enterotoxin, beta, beta 2, netF)</td>
</tr>
<tr>
<td><em>Neorickettsia risticii</em> (Potomac Horse Fever)</td>
<td>Consumption of aquatic insects harbouring infected helminths. No horse-horse transmission.</td>
<td>No source identified</td>
<td>PCR from blood or feces, Seroconversion (paired titres)</td>
</tr>
<tr>
<td><em>Equine coronavirus</em></td>
<td>Fecal-oral. Reservoirs likely healthy horses.</td>
<td>Clusters of fever and enteric disease recently recognized in adults. Rare diarrhea outbreaks in foals</td>
<td>PCR</td>
</tr>
<tr>
<td><em>Equine rotavirus</em></td>
<td>Fecal-oral. Shed by affected foal, as well as subclinically affected foals and adults. Usually affects 2–4 month old foals, so seasonality due to foaling season.</td>
<td>Common in foals on breeding farms</td>
<td>Fecal immunoassays, PCR</td>
</tr>
<tr>
<td><em>Lawsonia intracellularis</em></td>
<td>Fecal-oral but main sources unclear. Horse-horse transmission can occur.</td>
<td>Predominantly affects weanling foals so seasonality associated with foaling. Usually seen in fall to early winter.</td>
<td>Different response from most other outbreaks because exposure predates onset of disease by longer periods of time</td>
</tr>
</tbody>
</table>

4. Initial Data Collection

Understanding a problem is critical for proper intervention. Although understanding of the problem will evolve over time, as more information becomes available and the situation itself evolves, prompt collection of basic clinical, farm, and epidemiological data are necessary to put the problem into context and to help determine what initial actions should be taken.

Identification of even a single case of potentially infectious GI disease should trigger some basic information gathering to determine whether other affected horses may be present on the property or whether there are risks that further cases could develop. This can be complicated in some situations in which multiple owners and veterinarians are involved, but at a minimum, communication with facility personnel about the need to ensure no other horses are affected, should be performed.

When it is apparent that multiple horses might be affected, accurate information must be gathered promptly. This allows for determination of the scope of the problem, the number of horses affected and their locations. This also allows for identifica-
Implementation of horses that may have been exposed to a pathogen, something that is needed to facilitate cohorting into diseased, exposed, and likely unexposed groups. Thus, an initial step is gathering basic data, particularly the numerator (sick horses) and denominator (total number of horses at risk), both overall (entire farm) and for individual groups (e.g., individual barns, turnout groups, or other potentially distinct populations). This can range from very easy to very difficult to do, depending on the size, management, and record keeping at the facility. For example, a small farm with one owner makes gathering this information simple. A large farm with a dynamic population of horses from different owners traveling to different events can be more challenging. Requesting the facility to designate a liaison or point of contact who will assist the veterinarian with collection of these data can be critical.

In addition to numerator and denominator data, a variety of other data are important, including location of infected animals, co-mingling groups, potential sources of cross exposure (equipment, environment, personnel) and feed types, and sources and delivery dates.

Routine infection control and biosecurity practices, including routine isolation, cleaning and disinfection practices, movement patterns, cohorting, pasture/paddock management, and a range of other basic management practices should be queried to identify potential gaps, both for control of the ongoing problem and for future infection control strategies.

5. Initial Response

The initial response is independent of the diagnosis or data collected above, and must be initiated immediately. It is critical to initiate an appropriate response as soon as a potential problem is identified. Although there may be some differences in management of disease caused by different pathogens, the core of the infection control approach is the same for most GI pathogens and general measures should be implemented until a diagnosis is made. It is preferable to act quickly and aggressively at the start, with the ability to reduce to less stringent control protocols as appropriate over time.

The first response to a potential infectious GI disease is to separate the clinically affected horse(s) from the rest of the herd. This consists of both physical and procedural separation. This can be in a dedicated isolation stall, in a stall as far from other stalls/horse housing areas as possible or a separate pasture or paddock. In all circumstances, procedures must be put in place to reduce transmission of pathogens by personnel, fomites, or other animals (e.g., personal protective equipment, dedicated water buckets, feed tubs, and other equipment needed for the care of affected horses, limiting contact, working on affected horses last). In general, physical separation is more readily implemented than procedural separation, but both approaches should be used (e.g., as much physical separation as possible, combined with procedures to reduce any potential cross contamination).

Another early step is cohorting. This involves separation of groups of different risk statuses. Typically, this involves separation of diseased, exposed, and (hopefully) unexposed horses. These groups should be physically and procedurally separated from each other. Within the diseased and exposed groups, individual isolation is ideal. Individual isolation of unexposed groups, or forming small groups within the unexposed group, is also ideal, given that it can help contain any pathogen spread should one of the horses deemed unexposed actually be infectious. This is a potential risk because identification of these groups can be difficult, especially early in the process. In general, it is best to default to the highest risk group that is reasonable (e.g., if there is some concern a horse might have been exposed, consider it in the exposed group). Horses in the exposed and unexposed groups should be monitored closely for development of disease (e.g., fever, diarrhea, anorexia), because of the potential for incorrect group assignment.

Once initial containment has been established and treatment of sick horses is underway, the infec-

### Table 2. General Areas to Query When Investigating Potential Infectious GI Disease Incident

<table>
<thead>
<tr>
<th>Individual Horse</th>
<th>Facility</th>
</tr>
</thead>
<tbody>
<tr>
<td>Travel history</td>
<td>Number of affected, exposed and unexposed horses</td>
</tr>
<tr>
<td>GI disease history</td>
<td>Location of affected horse(s)</td>
</tr>
<tr>
<td>Antimicrobial drug exposure</td>
<td>Horse movement and mixing on the farm</td>
</tr>
<tr>
<td>Diet and diet changes</td>
<td>Facility vaccination and deworming regimens</td>
</tr>
<tr>
<td>Water source</td>
<td>Veterinarians that service the facility</td>
</tr>
<tr>
<td>Deworming history</td>
<td>Last introduction of new horses</td>
</tr>
<tr>
<td>Dietary supplement use</td>
<td>Routine infection control/biosecurity practices</td>
</tr>
</tbody>
</table>

...
tion control response can continue. Complete description of the outbreak response is beyond the scope of this document, but some important areas are discussed below.

If there is any likelihood that feed contamination is involved, the feed source should be switched as quickly as possible until contamination has been ruled out.

6. Investigation Team

Although uncommonly used apart from large or high profile outbreaks, establishment of an investigation or outbreak team is a useful response. This can gather all the relevant expertise and engage relevant stakeholders to optimize information gathering, communication, and outbreak response. The outbreak team can take various forms, depending on the situation, such as a group that formally meets in person on a regular basis throughout the outbreak, an ad-hoc team that discusses issues as needed, or a group that comes together virtually through electronic communications or participation in conference calls. It is important that all stakeholder groups have a member involved (e.g., in a boarding facility, that might be the farm owner, a representative of boarders, a representative of farm staff, and one or more veterinary personnel). Ideally, an expert in infectious diseases, and infection control is involved, either on site or for external consultation. A key concept is getting the help that is needed and doing that as early in the process as possible.

7. Diagnostic Testing

Although identification of the cause is not needed for implementation of an effective response, knowing the cause as early as possible is ideal. This can sometimes help identify specific treatments and specific infection control needs. It can also help identify potential sources of infection and zoonotic disease risks, and provide a basis for microbiological surveillance (e.g. Salmonella screening of exposed horses). Another benefit that cannot be overlooked includes putting a specific name to the problem; something that can help affected individuals deal with a stressful situation and allow them to read more on the topic from reliable sources such as the Equine Disease Communication Center (available at http://www.equinediseasecc.org).

Although identification of the cause may be simple in some situations, it is not always straightforward. A number of factors may inhibit successful testing, which are listed below:

Cost

In the absence of a rare situation in which there is government intervention, covering the cost of diagnostic testing is almost always the responsibility of owners or the farm. Testing can be expensive, particularly when multiple tests or serial testing is required. It is not uncommon to have situations in which testing cannot be performed or incomplete testing is performed (e.g., not testing as often as needed, only testing a subset of the horses because some owners refuse).

Interpretation of Results

Many pathogens that cause disease (including outbreaks) can also be found in healthy horses. A plan must be made prior to testing for how to deal with the various potential results. Testing of healthy horses can be useful in an outbreak response if those horses are deemed at risk of transmission and they are handled differently from negative horses. That is not always the case. Further, some diagnostic tests should not be performed on nondiarrheic feces (e.g., C. difficile ELISA), limiting the range of testing that can be performed.

Test Accuracy

Performance of diagnostic tests can be variable, with sensitivity, and specificity varying greatly between types of tests (e.g., culture vs polymerase chain reaction [PCR]), between tests of the same type (e.g., different ELISA kits), and between laboratories. Understanding the performance characteristics of any tests that are used is important to put the results into proper context. This can be difficult for some tests in which such data are not readily available.

Biological Relevance of Tests

Some tests that are available have limited likelihood of providing useful information and may simply confuse the situation. For example, Clostridium perfringens is a common commensal, and can overgrow quickly in response to (as opposed to being the cause of disease) enteric disease. Therefore, tests that identify this bacterium, or alpha toxin gene, a gene that is present in all types of C. perfringens and which is likely of little to no clinical consequence, can provide limited information. Some strains of C. perfringens may be relevant, and testing for specific toxins or toxin genes (e.g., enterotoxin, beta, beta-2 toxin, netP) may be more relevant but are less commonly performed.

When dealing with an outbreak, potential outbreak, or concerning single disease event, choosing which horses to test is an important consideration. Affected horses are the highest priority given that it is from those cases that a diagnosis will most likely be obtained. Testing of healthy individuals in the absence of confirmation or strong suspicion of the primary pathogen is highly questionable because of the overall low yield, associated cost, and difficulty interpreting results in healthy horses. Thus, the initial focus should be optimal testing (proper sample collection, handling, and test selection) of affected horses, with the goal being reaching a diagnosis. Once a diagnosis is made or strongly suspected, there can be consideration of broadening the scope of testing. This would involve a single
test type or narrower range of tests, focused on the presumptive pathogen, with the goal being identification of subclinically affected animals (when there would be a plan to manage these differently than other animals on the facility). Exposed or potentially exposed animals are the highest priority, but testing of all individuals on the farm is ideal, when possible, given that definition of exposed, and unexposed can be difficult. This will be used for decisions about isolation, to help determine the epidemiology of disease on the farm and to evaluate containment measures.

A variety of tests are available and choosing the optimal test or tests can be difficult because of the number of options, limited direct comparison between tests, test performance characteristics, costs, and suspected pathogens. PCR testing is becoming more widely available and has potential benefits of increased sensitivity and specificity compared with bacterial culture or virus isolation test methods, and short turnaround time. However, PCR also has the potential to be poorly sensitive and specific, depending on the quality of test design and performance. Understanding the test development, validation, and quality control practices used by chosen laboratories is important because these can vary greatly. A potential downside of PCR is the inability to recover an organism for subsequent testing (something that is most relevant with bacteria) and to confirm whether the pathogen is viable. Bacterial culture can provide an isolate for antimicrobial susceptibility testing and for typing, which might be relevant for patient management and outbreak investigation. Sometimes, combinations of PCR and culture may be useful, or a stepwise approach in which culture is performed on PCR-positive samples, particularly if PCR is faster and more sensitive.

PCR panels are increasingly available. These panels offer a range of diagnostic tests, typically at a substantially lower cost than running even a small number of individual tests. Advantages are the ability to get results from a wide range of potential pathogens at limited cost and more rapidly than moving through a sequential testing plan based on a negative initial single test. There may be disadvantages when tests that are included are minimally informative or when pathogens of uncertain relevance are included. It is important to recognize what PCR results mean. They suggest the presence of nucleic acids from target sequence. This usually means there was a viable organism in the sample but highly sensitive assays might detect transient passage of a microbe through the gut or nucleic acids from dead organisms. This may be of limited concern but it is important to remember that diagnostic tests of any sort are just one step in the diagnostic process. They provide important information but are not definitive and must be interpreted in the context of the affected horse, the affected farm, the epidemiology of the agent, and other testing results.

In recent years, assessment of the intestinal microbiota has received much attention. The gut microbiota is the complex microbial community in the gut, and there is increasing information implicating disturbances of this microbiota is associated with disease. It is now possible to use next-generation sequence-based methods to identify thousands of bacteria within a fecal sample, something that is impossible with culture-based methods. However, although it is clear that the microbiota is altered in GI disease, this is not yet a reasonable diagnostic tool. Although microbiota assessment could suggest a microbiota that differs from most healthy horses, knowledge of the microbiota is not yet to the state where microbiota assessment can confirm a diagnosis. Some healthy horses have microbiotas that would often be referred to as abnormal and some sick horses have unremarkable microbiotas. Therefore, microbiota testing can provide very useful information at the population level (e.g., comparing a group of diarrheic horses to those with normal feces), it it not yet appropriate for diagnosis of a specific disease. As knowledge advances, analysis methods improve and turnaround time shortens, this may be a useful tool in the future.

Testing of feces is the most common (and logical approach) in an outbreak of enteric disease. However, testing of other specimens from the horse maybe useful (e.g., blood for Neorickettsia risticii PCR). Other testing considerations include the following:

- **Hay:** Hay should be examined for visible evidence of contamination (e.g., mold, toxic plants, animal feces).
- **Pasture:** Pasture should be investigated to identify any contaminants or toxic plants, with testing for confirmation performed if indicated.
- **Grain/concentrates:** If a feed source is suspected as a cause of GI disease (e.g., antibiotic contamination), samples from different feed lots should be collected and tested.
- **Supplements:** If there is a potential link to supplements (or anything else a horse ingests), those should be tested.
- **Water:** Routine water testing can be performed, although bacterial limits applied to human drinking water do not necessarily apply. Water testing is most likely to yield an answer when specific testing is performed in response to a testing for a specific pathogen (e.g., Salmonella contamination of surface water).
- **Environment:** Environmental testing should be approached with caution. The equine environment is not expected to be sterile and a wide range of opportunistic pathogens can be found under normal circumstances. Identifi-
Infection Control Practices on Site
A rapid assessment of current practices and infection control needs must be performed. A wide range of topics must be covered, and the approach to these can vary greatly between outbreaks and facilities. Important areas to investigate and implement are below:

- Personal hygiene (e.g., hand washing)
- Personal protective equipment (e.g., routine outerwear; enhanced practices such as gown, gloves, and footwear covers)
- Personnel movement
- Horse movement
- Equipment-handling practices (e.g., management of water buckets, sharing of tack or stall cleaning equipment and other items)
- Methods for cleaning and disinfection of equipment and horse housing areas
- Cohorting
- Isolation and care of affected horses
- Protocols for visitors
- Protocols for visiting personnel such as farriers, veterinarians, and feed suppliers
- Vehicle access and cleaning
- Pasture and paddock management
- Manure disposal
- Pest control
- Wildlife access

8. Farm Containment/Isolation Recommendations

Specific aspects for implementation of a facility outbreak response are highly variable. A range of facility, disease, horse, regulatory, and logistical challenges may be present. It is often problematic to implement a strict infection control program, given that many standard equine practices are contrary to basic infection control practice (e.g., frequent movement on and off the farm with mixing outside horses, housing, or inconsistent grouping of horses when turned out). The economic effect of movement restrictions must be considered, but at the same time, the potential effect of inadequately containing an outbreak must not be ignored. This is often an emotional and contentious area that has to balance risk and benefit. Veterinarians rarely have any authority to quarantine a facility, but regulatory bodies (state, federal or provincial) may, depending on the disease and relevant legislation. Regulatory quarantine would be rare with GI disease (as opposed to, for example, equine herpesvirus [EHV]-1), although it is possible in some jurisdictions. More often, decisions to stop horse movement and implement isolation protocols must be made by facility owners/managers, given that they are typically the ones with ultimate control of the equine management plan. This is complicated on farms where multiple owners board or rent stalls. Unless boarding/renting contracts suggest the ability of farm management to initiate and enforce infection control protocols, there is often nothing stopping people from removing horses in the midst of an outbreak. This can pose a risk of dissemination of the disease agent(s), and the main approach to preventing this from happening is education and communication. When it is clear that keeping horses on the farm is the most ethical response and where people are considering taking their horses away, some key talking points would include the following:

- If your horse has already been exposed, they might infect the new farm. That could lead to a new outbreak, affecting other horses and people, and potentially creating liability concerns for you (because you knowingly took a higher-risk horse to a new facility).
- If your horse has already been exposed, it is possible that the stress of moving could increase the risk of it getting sick. It may be better off here where there will be close monitoring.
- If your horse has not been exposed, here is what we are going to do to make sure it stays unexposed.

Emphasizing risks posed by movement (to the horse owner and others) as well as demonstrating that a plan is in place to effectively control the current outbreak can help convince people to comply with infection control recommendations.

9. Communication

Communication is often overlooked and is something that can lead to mistrust, confusion, and errors in response. Common communications problems include the following:

- Failure to communicate with all relevant personnel
- Failure to provide prompt information
- Failure to provide complete information
• Failure to adequately explain why things are being performed
• Communication at an inappropriate level (depth of content, language)
• Failure to be consistent in decision making (e.g., designation of horse’s status or recommendation for management)
• Failure to provide frequent updates on the status of the situation and updates on the plan for dealing with the evolving situation

Good communication can help ensure recommended practices are followed, facilitate good information gathering, develop trust, or allay fears. Poor communication can result in mistrust, fear, inadequate compliance, and an ineffective response. A few basic tenets of communication are below:

1. Never announce a problem without providing your proposed plan for dealing with the problem now and as it evolves.
2. An information void does not remain for long. If people do not get the information from a good source, they will find other information somewhere.
3. The truth/factual information is rarely worse than the rumor mill. Providing clear information prevents people from relying on inaccurate information.
4. Credibility is hard to regain. If incomplete or misinformation is provided, credibility can be lost quickly.
5. Ensure everyone who needs to know finds out directly from the best source. If people or groups are left out, mistrust or anger can develop.
6. Update regularly. Even if there is no change, say something. People would rather hear that things are unchanged (or even if they are deteriorating) than nothing.
7. Be consistent. If a story changes, explain why. Ideally, have the same person (or people) directing communications and depending on the scope of the incident. It would be optimal for this person to have media training.
8. Be honest. Do not be afraid to say “we do not know.” However, follow any statement like that with an explanation of what is being performed to find out. (e.g., We do not know what the cause is yet. However, we are testing to determine the cause, and while knowing the specific cause would be nice, it will not change what we’re doing to start).
9. Explain why. If people do not understand why something is being performed, they may be less motivated to comply.

10. Outbreak Review
The natural tendency after an outbreak is over is to try to move on quickly and try to forget about it. However, in many ways, that is the opposite of what should be done. Outbreaks can provide important insight into future risks (GI disease or otherwise), the ability to respond, and strengths or weaknesses that were exposed in the outbreak response.

After an outbreak is over, a review of the entire event should be performed. This is ideally performed soon enough after the outbreak that memories are strong but after a long enough time for stressed, tired, or overburdened individuals to return to a more normal schedule and workload. The review should evaluate why the problem happened, all levels of the response, and the state of the farm at the completion of the outbreak. This can be used to identify measures that are needed to prevent further outbreaks and identify gaps or weaknesses in the response that can be strengthened should a similar problem ever occur. Typically, various measures can be undertaken to improve routine practices and improve outbreak response. The aftermath of an outbreak is a very teachable moment.

Related to this is a creation of a final report to relevant stakeholders (e.g., facility owner/management, people who have horses on the farm, veterinarians who were involved, farm personnel). This can provide a summary of the problem and the response, along with any measures that are being taken to improve routine practices. Communicating any changes is important to facilitate compliance, and compliance is often better when changes are initiated shortly after an outbreak given that memory of the effect of the outbreak provides motivation.

11. Conclusions
Outbreaks of infectious diseases are an ever-present risk with horses. Measures can and should be taken to reduce the risk of pathogen entry and spread, but many practices inherent in the equine industry mean that some residual risk will remain. Although all infections are not avoidable, the ‘preventable fraction’ may be substantial. A proactive infection control program can limit the introduction of pathogens, reduce the risk of sporadic disease, and reduce the risk of outbreaks that develop in response to pathogen entry. Basic approaches to preventive infection control and outbreak response are not overly cumbersome but are often inadequately used, increasing the assumed risk. Veterinarians are in a position to assist with prompt recognition of problems and implementation of an aggressive and logical but still practical outbreak response.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References
Equine Respiratory Disease, Differentials, and Options for Investigation and Control

Peter R. Morresey, BVSc, MVM, MACVSc, DipACT, DipACVIM(LA), CVA

In situations in which the outbreak of an infectious respiratory disease is suspected the attending veterinarian has multiple responsibilities. Primarily, the welfare and health of the affected horse or horses must be protected. In addition, management of the entire at-risk population to prevent disease dissemination must also be undertaken, affected parties must be communicated with, and financial implications of an outbreak weighed into but never allowed to compromise decision making. Author’s address: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070; e-mail: pmorresey@roodandriddle.com. © 2016 AAEP.

1. Introduction

The suspicion of a respiratory disease outbreak situation poses many questions to the attending veterinarian. First, what is the cause of the apparent disease? What will be the time course of the infectious and clinically apparent phases of the disease? What will be the duration of disease spread throughout the potentially exposed horses? How long after clinical resolution will recovered individuals be infectious to naïve contacts? Is there any potential for environmental persistence of the infectious agent, and will a reservoir be generated within the recovered population? With respect to the facility, how long must control measures, if any, remain in force? How long before transport of recovered individuals is possible without risking dissemination of disease? Of economic importance, how long should sale, showing, and breeding of recovered individuals be postponed? Regrettably, there is no one all-embracing answer to any of these questions individually or collectively. The attending veterinarian is forced to balance clinical and business continuity aims to the satisfaction of all affected parties, while holding welfare of the affected horse paramount. In some situations this can be a thankless task.

2. Epidemiological Considerations in a Potential Respiratory Disease Outbreak

Efficacy of Preclinical Infectivity and Its Effects on Control Measures

Control of contagious disease outbreaks is achieved largely by two means: the isolation of affected individuals, and both identification and segregation of all animals in contact with symptomatic cases. However, success of such control measures is largely determined by the proportion of disease transmission that occurred prior to the onset of clinical signs or asymptomatic infection, as well as the inherent transmission potential of the infectious agent itself, which is directly dependent on its reproductive capacity. The proportion of transmission prior to onset of clinical signs in infected individuals determines whether control measures based upon clinical signs will be effective in reducing new cases. It is
assumed, prior to the appearance of clinical disease in infected individuals, movement within the population allows all susceptible individuals an equal chance to become infected. For an outbreak to expand in the initial stages, multiple secondary cases must be induced by contact with the primary cases. The speed at which the outbreak occurs depends upon the interval between contact with the first clinical case and signs of disease in the subsequent contacts.

Date of Onset
Although the first horse displaying clinical signs presented for examination may be considered the first case by the farm personnel, close questioning may reveal that the index case was earlier. In this situation, the outbreak is already established and ongoing. This provides information regarding possible means of introduction to the herd and helps weigh the likelihood of various differential diagnoses and likelihood of various control strategies.

Attack Rate
This is defined as the number of new cases during the period of interest as a percentage of the entire population at risk at the beginning of that period. Attack rate varies depending on the etiological agent, with variations in rate of transmission, degree of infectivity, population susceptibility, and length of the pre-clinical phase of infection determining the rapidity at which the population seems to be affected. This can provide clues as to diagnosis in light of knowledge of the biology of candidate infectious agents.

Methods of Disease Transmission
Each infectious agent has a characteristic way by which it is most readily transmitted; however, this means of spread is not exclusive of other methods. Understanding of agent transference is crucial to the implementation of appropriate infection control measures. Transference can be divided into three broad categories: aerosol, direct, and indirect contact.

Aerosol spread is via droplets shed from the respiratory tract remaining in the air a sufficient time and in sufficient quantities to establish infection in another host. Infection may be established in a new host via exposure through the ocular or respiratory membranes.

Direct contact requires close physical contact between infected and susceptible horses allowing physical transfer of infectious organisms in body secretions, particularly respiratory. Horses kept together in close confinement are susceptible to transference by this route.

Indirect contact involves deposition of bodily secretions of sufficient infectivity to establish disease in a new host on surfaces common to infected and as-yet uninfected horses such as through shared trailers, shared water sources, or shared tack or wipe rags. Fomite transmission via contaminated handlers and their equipment is also part of this category. Care should be taken not to submerge the hose end or handle in individual water buckets if a common water source is used.

3. Examination of the Affected Horse(s)

History Taking of the Affected Horses
In addition to signalment recent medical history, interaction with other horses, transportation (if any), and vaccination status are important to determine. With respect to the clinical presentation of the affected horse(s), the onset, duration, and nature of the presenting signs should be accurately determined. Where the facility has a rapid turnover of resident horses, viral respiratory disease outbreak likelihood is increased. Where solitary horses, or a small herd kept in a closed environment, are affected with upper respiratory tract disease it is less likely that viral respiratory pathogens are responsible, although reactivation of latent carriers and shedding of virus is possible.

Before contact with a potentially infected and likely contagious horse, the veterinarian should determine whether personal protective clothing (gowns, gloves, boots, head coverings) should be used.

Physical Examination
Following observation at a distance of general demeanor, the pattern and effort involved in the thoracic respiratory excursion should be noted, this giving clues as to the extent of respiratory tract involvement. As part of an examination directed toward infection of the upper respiratory tract, mucous membrane color, moisture, and refill time should be assessed. Facial symmetry and the presence of any swellings should be determined. The nature, color, and odor of any ocular or nasal discharges should be noted, and whether they are present unilaterally or bilaterally (which suggests involvement of the paranasal sinuses). The pharyngeal area should be palpated: the size of the submandibular lymph nodes, any distension of the guttural pouches, and retropharyngeal masses (likely abscessed lymph nodes) can be assessed.

Differential Diagnosis of Pyrexia
Fever is likely to be one of the primary reasons that veterinary evaluation of the affected horse or horses is sought. There are numerous infectious agents that can be associated with high fever in the individual horse, rarely in outbreaks, but not contagious upper respiratory tract infection:

- Respiratory system
- Bacterial pneumonia, pleuritis, abscessation
- Gastrointestinal tract
Anaplasma phagocytophilum, Neorickettsia risticii, Salmonellosis, Clostridiosis

- Genitourinary system
- Pyelonephritis, cystitis
- Noninfectious conditions
- Environmental, humidity, strenuous exercise, transport stress, anhidrosis, hypertrichosis

Candidate Diagnoses for Respiratory Disease Outbreaks (N.B state reporting requirements differ)

**Equine Herpesvirus**

Infection with equine herpesvirus (EHV)-1 and EHV-4 is widespread and predominantly subclinical, with latent infection commonplace. Transmission is usually dependent upon direct contact; however, mechanical spread via fomites and inoculation by aerosol is likely, particularly in those situations in which horses are housed closely together. Abortion, respiratory, and neurological disease has been associated with infection, with resulting disease severity dependent on viral subtype, strain, and host response to infection. Rate and degree of spread throughout a group of horses is variable, with sometimes only a small number of cases displaying overt disease. In situations in which respiratory disease becomes clinically apparent, infection results in moderate-to-high fever (≥102.5°F), an occasional shallow cough, and the acute onset of a serous to mucopurulent nasal discharge. Latent infection is clinically silent.

Following experimental infection, viral shedding persisted for up to 14 days; however, viremia has been demonstrated in some cases for many weeks post inoculation. Due to widespread latency, all horses on the premises can be considered potential carriers. Recrudescence of latent infection following stress (transport, social) leads to nasal shedding of virus and may or may not show signs of disease, this being dependent to some degree on the general health of the host.

**Equine Influenza Virus**

Equine influenza virus (EIV) is highly contagious and spread readily by the aerosol airborne route. Dissemination through a small number of densely housed horses may be rapid. Unvaccinated horses experience a rapid onset of high fever (to 104°F), profound depression, high volume serous progressing to mucopurulent nasal discharge, and a harsh dry cough. Where vaccination has been efficaciously applied, manifestation of disease is considerably attenuated, with fever likely absent and only nasal discharge and an exercise-induced cough noted. If herd immunity is high, the number of subclinically infected individuals will be high. Equine influenza has been shown to be unpredictable in its ability to cause outbreaks within vaccinated populations, due to antigenic drift inherent in this virus family.

Shedding of EIV post infection from naïve horses can be expected for up to 10 days, with vaccines shedding for a significantly shorter period. Given that infection generates considerable immunity, the long-term carrier state is not produced.

**Equine Arteritis Virus**

Infection with equine arteritis virus (EAV) causes a nonspecific syndrome. Fever and depression are typically present; however, any of the following may appear singly or in concert with other signs: edema of the distal limbs, periorbital region, ventrum, scrotum, prepuce, and mammary gland; conjunctivitis; abortion; and dermatitis (uncommon). Following establishment of infection, horses shed virus in all bodily secretions: ocular, nasal, urine, feces, and in the case of sexually intact mature male, semen. Transmission of EAV occurs by both the respiratory and venereal routes. Respiratory transmission requires some degree of direct contact; airborne transmission has not demonstrated, and reports of prolonged minimal separation and a shared airspace not facilitating infection of an entire herd exist.

Spread of disease via the respiratory route is therefore comparatively slow.

With respect to venereal transmission, infected mature intact males will shed virus in their semen in the immediate period post infection. Persistence of the carrier state is variable in duration and dependent upon the presence of T, with virus shed from the accessory sex glands.

**Streptococcus equi Subspecies equi** (Strangles)

Infection with *Streptococcus equi* subspecies equi is characterized by varying degrees of fever, depression, purulent nasal discharge, and pharyngeal lymphadenopathy depending on age and immune status of the affected individual. Infection may be asymptomatic, mild, or occasionally disseminated throughout the lymphatic system in younger horses. Rarely, widespread vasculitis occurs (purpura hemorrhagica), which can result in significant cutaneous lesions and laminitis. Transmission requires close contact between the infected horse and susceptible individuals; however, fomite spread is well documented. Point sources (e.g., water troughs, hoses, feed bins, cleaning equipment and locations where horses congregate such as stalls and pens) are commonly associated with spread throughout a herd given that these are favorable environments for deposition and persistence of infected secretions.

Depending on traffic at a water source, outbreaks of clinical disease can therefore seem rapid and widespread due to the compressed timeframe over which successful inoculation can occur.

The majority of infected horses eliminate the bacteria rapidly; however, not all individuals achieve bacteriological clearance. Generation of the carrier state is important in persistence of the infection on a property, disease induction in new arrivals, and reoccurrence of disease within an apparently closed...
Other Viruses Associated With Upper Respiratory Tract Infections

Regardless of the causative agent, clinical signs are similar: fever, mucopurulent nasal discharge, and some degree of cough. Diagnostic efforts skewed toward the above-mentioned agents will fail to achieve an etiological diagnosis in large percentage of clinical cases. In others, infections with multiple agents can occur. EHV-2 and EHV-5 are found as co-infecting viruses, and it is thought that they may predispose horses to infection with more common agents. Equine adenovirus and equine rhinitis virus A and B are also found in cases of clinical upper respiratory disease; however, consistent pathogenicity is debated as they can, like EHV-1, be recovered from unaffected horses as well.

Making the Decision to Institute Barrier Precautions, Containment Procedures, and Quarantine Protocols

Clinical impression leading to a presumptive diagnosis will be, in the early stages of a potential outbreak, the determining factor in the extent of the institution of biosecurity measures. Effectiveness of isolation protocols is dependent upon a low rate of disease transmission prior to the onset of overt clinical signs in the first recognized case(s). Where considerable transmission has occurred before the onset of clinical signs, isolation protocols for first cases and identified in-contact horses are unlikely to blunt the onset of an outbreak; however, spread to other locations may be curtailed by institution of appropriate measures in a timely fashion on the affected property.

In real-life clinical situations, there will be delays between the recognition of disease and the institution of barrier precautions and isolation protocols. The timeliness of segregation of affected horses is in large part dependent on the nature of the clinical signs, severity of the ensuing illness, the time course of these events, and how prepared the facility is to implement a response plan for containment of a contagious disease incident. Delays will therefore, in some cases, have the potential to significantly reduce the effectiveness of these control measures.

4. Diagnostic Testing

Importance of an Etiological Diagnosis

Where achievable, identification of the infectious agent greatly aids in the design and implementation of effective control measures. For agents with a propensity for rapid aerosol spread over considerable distances, for example EIV, rigorous control measures including strict barrier precautions and avoidance of common air spaces are necessary. This is in contrast with agents such as EHV, EAV, and Strangles, which require closer contact between horses for droplet transmission to occur, where protective clothing, gloves, and the avoidance of shared equipment may suffice.

Collection of Samples

Diagnostic sampling of the equine respiratory tract has been well reviewed. The upper airway can be sampled by swabs or lavages. Swabs are primarily used for the detection of viral pathogens (culture, molecular, immunoassay) although specific organisms can be recovered (e.g., Streptococcus equi subspecies equi). Lavage of the guttural pouches, either with or without the aid of endoscopy and nasopharyngeal flushes provide samples suitable for culture and molecular diagnosis.

Culture

Bacterial culture of swabs is complicated by the numerous nonpathogenic organisms present; however, Streptococcus equi subspecies equi (culture, polymerase chain reaction [PCR]) can be identified by this method. When aseptic technique is practiced, guttural pouch aspirates and lavages should yield representative cultures.

Molecular Techniques: PCR and ELISA

Respiratory secretions or whole blood can be collected for the assessment of the presence of RNA or DNA of specific infectious agents by the PCR. Both viable pathogens and nonviable genetic material will be detected, which may lead to a false assumption of infectivity in some cases. Antigenic proteins characteristic of a particular infectious agent may be revealed by ELISA testing. Molecular methods enable pathogen detection more rapidly than virus isolation or bacterial culture. The known major pathogens (EHV-1–5, EIV, EAV, Streptococcus equi subspp. equi) and less-recognized causes of respiratory infections (equine adenovirus, equine rhinitis virus A or B) are readily recognized with high sensitivity by these means.

Comprehensive multi-agent respiratory pathogen panels are available and cost effective. Turnaround time varies from 1 to 4 working days. During this period, given that more clinical cases may become apparent, it is essential that ongoing efforts to diagnose and contain spread of infection continue.
Serology
To retrospectively diagnose viral respiratory diseases, paired serum samples can be assessed: an acute sample collected during the febrile phase, followed by a convalescent sample 14–21 days later. A 4-fold increase in titer is considered a positive test result and evidence of recent exposure to the particular agent. However, a positive test result suggests exposure not always active infection, and a negative test result does not absolutely rule out disease.

Sample Handling and Transport
Microbiological swabs and lavages for bacterial culture should be handled with aseptic technique to avoid contamination and kept refrigerated until plating of samples is possible. Given that the PCR test is extremely sensitive, care must be taken to avoid contamination of the sample at all stages of sample collection and subsequent handling. Whole blood should not be exposed to heat sources, and clotting of the sample must be avoided, necessitating thorough mixing of the anticoagulant at the time of sample collection. Samples for serology should be allowed to clot at room temperature, then if a delay in assay is expected, serum can be drawn off the clot for separate storage (freezing is possible). In all cases, sample collection, handling and storage requirements of the particular diagnostic laboratory selected for assay of samples should be known in advance and strictly adhered to.

5. The Facility as Your Patient
Distribution and Mixing of Horses on the Property
Many disease models simplistically assume that the horse population is homogenous and each individual has an equal chance of interacting with and therefore being infected by any diseased individual. In reality, a number of factors affect the spread of an infectious agent through a resident population of horses.

The age distribution of the population affects the rapidity and degree of disease spread. With increasing average age of the population, disease incidence is potentially reduced due to the likelihood of pre-existing immunity within mature individuals resulting from previous exposure regardless of the individual variation in susceptibility of younger potentially naïve horses present.

Interplaying with demographics is population density. Where crowding is present, immunity of mature individuals has a more pronounced effect in reducing spread among young naïve horses. This effect is less important where stocking density is lower. Also, clustering of horses occurs due to ownership and management factors creating sub-populations, providing uneven chances for contact with infectious individuals present in other sub-populations.

These factors should be considered when investigating an outbreak where horses in one part of the facility or belonging to one particular owner are differentially infected compared with the overall populace. This provides clues as to where the first recognized clinical case may have arisen, the most susceptible members of the population, and also the expected time course of the outbreak.

Population Structure and Movement of Resident Horses and New Introductions
Generally a predominantly young, more densely stocked facility is more at risk from a rapidly spreading disease agent. Consequently, with consideration of the agents involved, addition of new horses to the property while infectious disease may be present (diagnosed or as yet clinically silent) is more likely to result in infection of the new arrival. Similarly, introduction without adequate isolation procedures of a new horse to a property densely stocked with a younger demographic is more likely to result in the introduction of an infectious agent with the ability to spread throughout the resident population. A high proportion of pregnant horses may lower herd immunity due to the inherent immune suppression of pregnancy.

In the first instance, movement of horses around the facility and mixing of individuals from different age groups should be discontinued until a diagnosis is obtained and control of new infections achieved.

Biosecurity Implications and Actions for Various Infectious Agents
Ease of transmission and persistence of the infectious agent within the individual, population and facility has profound implications for biosecurity activities to attempt control of disease going forward.

At minimum, disposable gloves should be used when handling all horses resident on the property. Disposable gowns or coveralls should be used where there is a risk of contamination to operators (coughing, production of contaminated aerosols or secretions), these being changed between barns or individual horses depending on the ability of the facility to allow sufficient segregation of horses. Hand washing or the use of sanitizing gels should be instituted between horses and barns. Feeding and cleaning utensils should be disinfected and not transferred. If the operation is of sufficient size and there are sufficient staff available, nomination of specific personnel to defined areas of the facility will reduce the potential for fomite spread to other barns on the property as yet unaffected.

Infection with respiratory forms of EHV may take several weeks to spread throughout a herd situation, making recognition of an outbreak sometimes difficult. The slow rate of spread makes isolation of affected and in-contact individuals an effective means of controlling spread during outbreaks once identified. Where clinical disease is mild, isolation of clinical cases and twice-daily monitoring for
fever of contacts practiced. Where sufficient segregation of these groups is possible, and rigorous barrier precautions put in place, normal operations of the farm are possible to continue. In situations in which abortigenic or neurological cases are present, strict isolation of the facility, movement control of the resident horses, notification of state authorities (if required by law), and suspension of operations is mandatory.

In the case of EIV, a highly contagious nature and high rate of subclinical transmission necessitates closure of affected facilities and cessation of introduction of horses on to the property. In situations where regular contact between all potentially affected individuals occurs (e.g., large numbers turned out together regularly), segregation of horses will not prevent spread of infection, and vaccination of the herd in the face of an outbreak is unlikely to be of benefit as considerable spread will have occurred prior to recognition of the initial clinical cases. Where limited or episodic contact occurs between resident horses, prompt boosting of immunity by vaccination (e.g., intranasal route) may be of benefit to rapidly generate local immunity and curtail spread throughout the herd.

Where infection with EAV is suspected, outbreak control is accomplished by cessation of all breeding-related activities and movement control, isolation of affected horses, and segregation of all (infected and uninfected) resident horses. Notwithstanding the requirement for close contact to enable respiratory spread, potential for environmental contamination and fomite spread due to virus shedding by multiple routes, and the significant consequences of the spread of infection (chiefly reproductive), necessitate strict control measures to be instituted.

Transmission of Streptococcus equi subspecies equi infection can be effectively curtailed by the early detection of infected and shedding individuals by serial nasopharyngeal sampling. Three groups of horses will be identified: known infected or those with compatible clinical signs (fever, nasal discharge, lymphadenopathy); suspect cases being those horses deemed to have had sufficient contact with known infected horses and those displaying premonitory signs of infection (fever); and a clean group of those believed to have not had contact with infected horses or their secretions. Strict barrier precautions should be instituted between all horses on the property, with horses identified in the first two groups listed previously being placed in the appropriate group under strict isolation conditions. Should disease progression be noted in any horse in the suspect or clean groups, that horse is escalated to the group comprising horses in the next level of disease category. Horses do not leave their group until the outbreak is declared over and pre-ordained criteria for freedom of disease have been met by all individuals in their group of which they will have had close contact during segregation. Furthermore, unless strict isolation can be assured for new arrivals, no horses should enter the property until the outbreak is demonstrated to be over.

The attending veterinarian has a central role in the practical application of control measures. When a disease outbreak is first recognized, the veterinarian should personally examine the facility and use their expertise to design control measures compatible with the facility and personnel available. Periodically, reassessment of the efficacy of control measures should be conducted, and is best achieved by direct inspection of the property.

Decontamination and Disinfection Where Required

Persistence of infectious respiratory disease-causing agents varies, and is summarized in the following American Association of Equine Practitioners (AAEP) infectious disease guidelines resource: http://www.aaep.org/-i-151.html. The majority of infectious respiratory disease causing agents do not persist outside the body for prolonged periods. Viral causes require cell association, moisture, or rapid transference to avoid inactivation; however, the period is variable between agents (e.g. EHV several weeks, EIV ≤ 3 days). Streptococcus equi subspecies equi has been demonstrated experimentally to persist up to 63 days in favorable environments free of competition from environmental flora, although this should be interpreted with caution due to the artificial conditions inherent in this study. A period of 30 days is stated in the AAEP guidelines.

Where gross contamination with respiratory secretions has occurred, and can be localized to manageable common horse areas, decontamination of the infected environment involves removal of organic matter, physical cleaning and disinfection to render infectious agents inert. The veterinarian is required to assess the nature and extent of the surfaces where decontamination is to be attempted, to advise upon the practicality of attempting this procedure, and to offer a reasoned opinion as to the utility of the financial and labor expenditures involved.

Removal of bedding, fecal material, and contaminated feed is the first step to decontamination of the environment. During this phase it is important not to spread infected material; therefore, care should be taken by handling it separately and with appropriate barrier precautions. Cleaning begins after organic matter has been removed, and includes scrubbing of the walls and floors with a detergent solution and then rinsing with water. Avoid dissemination of infectious agents by droplets. Once the area has dried, disinfection can be performed.

There are various categories of disinfectants: peroxycen products, phenolics, chlorine, iodophors, and quaternary ammonium compounds. Peroxycen products have a broad antimicrobial spectrum, with activity in the presence of organic matter. Phenolic disinfectants are effective in the presence of organic debris and will kill bacteria and viruses.
Chlorine-containing compounds are inactivated by organic material necessitating a thorough cleaning prior to usage are corrosive and will cause discoloration of contact surfaces. Iodophors are also corrosive and rendered inactive by organic material. Quaternary ammonium compounds are also inactivated by organic material, are incompatible with soaps and detergents, and may be less effective against some infectious agents than other compounds.

Reinstitution of Normal Operations

**EHV**

Isolation for up to 28 (≥21) days following the last clinical case may be required. Discontinuing of isolation protocols is dependent upon all exposed or infected horses being tested by nasal swab and displaying a negative result by PCR.

**EIV**

Isolation procedures can be removed 21 days after resolution of the final clinical case. Environmental persistence is short (≤3 days).

**EAV**

Once virus isolation of nasal or pharyngeal swabs and blood is negative, horses can be released from control measures if there has been resolution of clinical signs and freedom from new cases for 3–4 weeks.

*Streptococcus equi subspecies equi*

For apparently recovered horses, it is recommended that three consecutive weekly PCR and culture samples are obtained by nasopharyngeal washing. All must be negative to categorize the horse as minimal risk to in-contact horses. Should a positive result be obtained on any sample, further diagnostic investigation is indicated to find the focus of infection. Thereafter, treatment followed by comprehensive retesting is indicated. For those horses without known exposure or fever for a period of 21 days, testing is not indicated.


Following the outbreak, containment, and eventual elimination of any contagious disease, an isolation and monitoring policy for all new arrivals is instituted forthwith.

**6. Communication With/Between Interested Parties**

Control of disease outbreaks depends upon isolation of affected individuals and determination of their contacts, as previously stated. Essential to this approach is rapid dissemination of information pertinent to accurate diagnosis of infected horses, this in no small part dependent upon concise case definition. Close liaison between the veterinarian, responsible party for the facility (if multiple horses are present), and nonresident horse owners is essential.

**Ethical Responsibilities**

Client confidentiality must be maintained but this can never be at the expense of timely and appropriate veterinary intervention during a respiratory disease event. Documentation of clinical cases, obtaining of appropriate diagnostic samples, appropriate handling and submission of biological samples in a timely fashion to maximize the opportunity to make an accurate diagnosis, and a coherent disease control plan that can reasonably be expected to curtail the spread of the disease agent within and externally to the affected property are the responsibilities of the attending veterinarian. Economic concerns are often present, being not limited to costs of diagnosis and treatment; immediate foregoing of boarding, show and breeding income, and reputational damage to the affected property affecting future income potential. These cannot trump expeditious management of the outbreak.

**Legal Responsibilities**

Requirements for notification of state veterinary regulatory authorities and legality of sharing information with lay parties regarding diagnosis of particular infectious respiratory disease agents varies depending on the jurisdiction. The veterinarian is legally bound to follow the applicable regulations with respect to the identity of the organism present. Requirements for state veterinary regulatory notification of infectious diseases vary between states. Contact information for state veterinary officials, and succinct information pertinent to equine diseases can be accessed as follows: http://www.equinediseasecc.org/diseases.aspx.

**7. Challenges of the Veterinary Role in Infectious Disease Outbreaks**

**Coherent Communication**

It is only natural that emotional responses and misinformation will abound where multiple owners with varying levels of understanding and risk aversion are involved. Integrity of the veterinarians’ message will be protected by coherent written documentation of clinical case definition, recording of clinical findings and results of laboratory testing, recommendations regarding barrier precautions and isolation protocols and observation of what was instituted, and direct communication with affected parties where required. Definition of what criteria will be used to consider the outbreak resolved and mechanisms by which normal functioning of the property can be restarted, should be documented, and communicated close to the time of onset of the outbreak to avoid the appearance of an open-ended problem devoid of potential resolution.
Client Confidentiality

The veterinarian and their support staff should ensure that no information is shared or implied during interactions with peripheral parties. The economic consequences to owners and managers affected by the disease outbreak can be significant, and the opportunity for aggrieved individuals to seek redress through the veterinarian’s statements and actions must be avoided. Social media has the potential to seriously compromise veterinary efforts to maintain client confidentiality. In these situations, counseling of all interested parties (veterinary, facility management, horse owner) on the inability to retract statements and images disseminated is prudent.

Comprehensiveness of Approach

Reputation of the veterinarian will be enhanced by a rapid assessment of the disease outbreak situation, implementation of timely and accurate diagnostic procedures, promotion of the welfare of the affected horses through comprehensive treatment, transfer of important diagnostic information to appropriate parties, and impartial but compassionate application of control measures for all affected and in-contact horses present on the property.

8. Take-Home Message

There is a tendency to 'shoot the messenger' when a significant respiratory pathogen is diagnosed leading to the necessity for restriction of horse movement and curtailing of facility operation while steps are undertaken to control the disease. A proactive veterinary response is needed: depending on the agent involved, considerable spread of infection may have occurred before the first case is recognized, or the inherent virulence of the organism may allow transmission at a sufficient rate to render isolation protocols ineffective to contain further infections.

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Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

Role of State Animal Health Officials in Protecting Equine Health: Response to Reportable Equine Diseases in Your State

Katherine Flynn, BVMS

State Animal Health Officials (SAHOs) are responsible for developing and implementing effective animal health regulations and ensuring utilization of science-based disease control measures to control regulated diseases. SAHOs rely on the expertise and assistance of equine practitioners in assisting them in protecting the national equine population from diseases of regulatory importance. Diseases of regulatory importance may vary from state to state; therefore, the practitioner must be aware of the equine diseases that they need to report to the SAHO and potential responses by the SAHO. Ultimately, collaboration and communication between equine private practitioners and the regulatory officials across the United States is essential for protecting and promoting the health of the U.S. equine population. Author’s address: Equine Staff Veterinarian with the California Department of Food and Agriculture, Animal Health Branch, Equine Programs, Sacramento, CA 95833; e-mail: katherine.flynn@cdfa.ca.gov. © 2016 AAEP.

1. Introduction

State animal health officials (SAHOs), under the direction of the state veterinarian, protect animal agriculture in their respective states through disease surveillance and implementation of movement regulations and control activities for regulated diseases. The SAHOs in each state are the experts in livestock health regulations and are responsible for development and enforcement of state animal health laws. State animal health laws are typically based on federal regulations outlining federal disease control programs; however, state laws may also include state-specific laws that go beyond those included in federal disease control programs to address industry designated livestock disease risks of concern within a state.

Historically, SAHOs primarily focus on protecting the health of food-producing animals such as cattle, sheep, swine, goats and poultry to ensure a wholesome, healthy, food supply for the U.S. consumers. The available funding and workforce efforts are focused on diseases or situations that pose public health or catastrophic animal health risks. Due to this prioritization of funding and personnel, limited resources and expertise may be available to address equine health issues in a state. In addition, during the past ten years, reduction in state and federal budgets and personnel have significantly affected the availability of resources in many states.

At a minimum, SAHOs monitor equine diseases and equine movement in states to mitigate threats and to effectively respond to disease incursions. Equine regulatory disease responses include identi-
fying diseased equids, those with positive test results for diseases regulated in the state, conducting epidemiologic investigations, tracing and potentially testing exposed animals, assessing and determining quarantine implementation and release parameters, implementing appropriate disease control methodologies, issuing movement restrictions when appropriate, and reporting disease investigation findings. Implementation of science-based biosecurity measures is critical to protecting the health of the national equine population from diseases of regulatory concern.1

2. State Reportable Disease Lists—Equine
Equine diseases of regulatory concern are those that have potential state, national, or global significance. For example, an incursion of a foreign animal disease, such as African horse sickness in the United States would have significant national and global impact given that the U.S. equine population is native to this disease and could result in high mortality and immediate trade implications including likely movement restrictions on export of equids from the U.S. In contrast, an introduction of Streptococcus equi subspecies equi into a group of horses on a U.S. farm would result in limited fatalities in the affected horses and minimal, if any, restrictions on trade. Both diseases are of concern to the U.S. equine industry; all states require reporting of African horse sickness if it were to occur in the U.S. but only a few states require reporting of strangles cases.

The World Organization for Animal Health (Office of Epizootics International [OIE]) member countries must report the occurrence of any disease deemed by OIE as of international significance. The list of international reportable diseases can be found at http://www.oie.int/animal-health-in-the-world/oie-listed-diseases-2016/. The following diseases of equids are included on the OIE Reportable Disease List: African horse sickness, contagious equine metritis (CEM), dourine, Eastern and Western equine encephalomyelitis, equine herpesvirus-1 (EHV-1), equine infectious anemia (EIA), equine influenza, equine piroplasmosis (EP), equine viral arteritis, glanders, rabies, West Nile virus, and Venezuelan equine encephalitis. Detection of a foreign animal disease, one not known to exist in the U.S., would have major economic and trade effects and require immediate state/federal notification and prompt implementation of control measures to protect the U.S. equine population.

In the U.S., the National Animal Health Reporting System (NAHRS) is the U.S. reporting system for the OIE-reportable diseases. SAHOs submit monthly reports of the occurrence of confirmed OIE-reportable diseases in livestock in their states to U.S. Department of Agriculture (USDA) via NAHRS. The reporting is as a yes or no for occurrence of the listed disease in the state. The NAHRS Reportable Diseases list is available at: https://www.aphis.usda.gov/aphis/ourfocus/animal health/monitoring-and-surveillance/oa_disease_reporting/ct_disease_list.

It is important to note that SAHOs are responsible for monitoring equine disease trends in their states to assess risks and to determine triggers for enhanced disease control measures in the state. Each state develops and maintains a state reportable-disease list, which might include endemic equine diseases of concern to the state’s equine industry, in addition to OIE- and USDA-reportable diseases and conditions. SAHOs determine which diseases are reportable to their office, often in consultation with industry. Industry-driven reportable diseases may include diseases such as strangles or pigeon fever. The state veterinarian determines who is responsible for reporting the disease or condition (i.e., diagnostic laboratory, veterinarians, owners, etc.), to whom to make the report (state/federal official), when it should be reported (i.e., immediately [within 24 h] or within 2 days or within 30 days), and what should be reported (suspicous signs or conditions, laboratory-confirmed case, confirmed disease agent detection). For example, equine herpesvirus myeloencephalopathy (EHM) was added to the California Reportable Animal Disease List in January 2011. Before 2011, California SAHOs had been monitoring the situation and noted an increase in confirmed neurologic cases of EHV-1. Nationally, the increase in the number of EHM outbreaks warranted further industry research and discussions to determine appropriate actions that should occur when this disease is in California. The California Department of Food and Agriculture Equine Advisory Committee agreed that the risk of EHM necessitated regulatory actions to protect the health of the California equine industry and a decision was made to add EHM to the California Reportable Disease List.

Inconsistencies in state reportable animal disease lists are a recognized challenge to those in the equine industry and the lists represent a variation in equine disease risk and control issues across the United States. Private practitioners are encouraged to familiarize themselves with the reportable disease list in their state and to communicate directly any concerns regarding the state reportable disease list to SAHOs.

3. Detection of Reportable Disease
The private practitioner is essential in protecting the health of the equine industry given that they are the first line of defense and response to a regulatory reportable disease situation. If a reportable disease is suspected, the private practitioner is urged to promptly contact the local state or federal animal health official to discuss the situation. The state regulatory official can provide immediate guidance on management of a suspect case specifically related to sample collection, specimen handling, appropriate diagnostic tests to request, and implementation of biosecurity measures. In addition, the
SAHO may be aware of other similar incidents and thus potential exposure risks may be identified through this initial discussion between the equine practitioner and the SAHO. A list of contact information for the State Veterinarian is available at http://www.usaha.org/Portals/6/StateAnimalHealthOfficials.pdf or at http://equinediseaseecc.org/veterinarians.aspx.

Detection of a regulated reportable equine disease results in the SAHO assessment of disease risks and determination of appropriate disease control measures to implement, such as quarantine, movement controls, and biosecurity measures. The regulatory response depends upon the disease agent detected and the epidemiologic investigation findings. Depending on the disease, a regulatory action, such as quarantine, may be instituted for a suspect case, but oftentimes regulatory action is not taken until a confirmatory diagnosis is made. However, it is important to note that reporting of a disease situation does not necessarily dictate a regulatory response, given that the SAHO investigation of the situation may deem control measures unnecessary and thus the report of a monitored condition or disease may require no SAHO action. For highly infectious and highly contagious diseases, expansive quarantines and movement restrictions may be essential to quickly and effectively control disease. Humane euthanasia may be the only option for protecting the equine population if and when a disease cannot be controlled. For the more common equine regulatory diseases, such as EIA, EP, equine viral arteritis, and CEM, there are federal guidance documents or recommendations for handling suspect and positive cases. Unfortunately, there are no federal equine domestic control program regulations and very limited federal disease control standards, which can lead to inconsistent handling of equine regulated diseases across the United States.

4. Examples of Responses to Reportable Disease Incidents in California

EHM

In February 2012, there were two confirmed EHM incidents in California. One incident involved a 350-horse boarding facility and one incident involved a 500+ horse polo facility. Upon notification, the SAHO visited each site and in consultation with the private practitioner performed a risk assessment to determine appropriate quarantine parameters and biosecurity measures.

Biosecurity risks identified by the SAHO at the boarding facility included lack of isolation facilities, numerous daily visitors (14 trainers, eight onsite farriers, an onsite veterinarian practice, and an onsite training facility), sharing of equipment, communal water and carrot bins, frequent commingling of horses, lack of horse inventory monitoring (i.e., no records of horse movements), frequent movement of horses on and off the premises, and nonexistent biosecurity measures. Based on the numerous movements at the facility and the commingling of horses, the entire premises was quarantined and recommended biosecurity measures were implemented. Due to slow implementation of biosecurity and failure to immediately implement adequate isolation, febrile EHV-1 cases and horses with nasal discharge cases continued to be diagnosed and the quarantine was prolonged to 34 days at this facility.

At the polo facility, the private practitioner was presented with a horse displaying acute onset of neurologic signs, specifically severe hind limb ataxia, urinary bladder atony and eventual recumbency with inability to rise. The neurologic horse was immediately removed from the population and isolated and subsequently euthanized. Upon laboratory confirmation of EHM, the SAHO was contacted. Biosecurity risks identified at the polo facility included riders’ sharing of horses and sharing of equipment between horses. Minimal but some biosecurity measures were in place on the polo grounds. Based on the extensive commingling of horses and sharing of equipment between horses, the entire premises was quarantined and a restricted training and exercise plan was implemented to eliminate commingling of horses on the operation. The polo facility was very prompt in isolating and removing the sick horse within 12 hours of initial detection of disease as well as implementing necessary enhanced biosecurity measures. They were also prompt in the cleaning and disinfecting of the index horse’s stall area. No additional cases were detected on the premises and quarantine was effectively released in 21 days from the time it was initiated. Subsequently, the facility implemented an EHV-1 control plan. This same facility experienced an EHM case in 2016; the EHM case was euthanized within 3 hours of clinical onset of neurological signs. Based on lessons learned from the 2012 incident, the operation had implemented routine biosecurity and disease control measures to minimize disease risk on the premises. The 2016 risk assessment demonstrated a marked reduction in risk of potential disease spread, thus the resulting quarantine was restricted to one stabling area containing 70 exposed horses allowing for business continuity on the other parts of the premises. The prompt detection and routine implementation of biosecurity enabled the facility to quickly eliminate the source of infection and prevent disease spread. The quarantine was released 14 days after the removal of the clinical case given that no additional clinical cases were detected and the likelihood of exposure of horses on the operation to EHV-1 based on routine biosecurity that was in place was minimal.

In general, SAHOs take action to prevent spread of EHV-1 off of the affected operation but SAHOs may have a limited role in assisting the operation in reducing spread of the virus at the premises level. Thus, the private practitioner’s role would be to assist their client with implementation of appropri-
ate on-farm disease control measures. In states where the EHM is not reportable, the SAHO does not have any role in disease control, thus all control efforts are the sole responsibility of the private practitioner.

During the last 5 years, regulatory officials across the U.S. have investigated numerous EHM cases and continue to learn how to most effectively assess risk and manage these incidents while making science-based decisions. In 2014, the United States Animals Health Association (USAHA) hosted a meeting to discuss the changes in EHM and science-based response options for state animal health officials. Subsequently, great efforts have been made to have regulatory responses be science based. However, there are still variations among the regulatory responses by SAHOs. Ultimately, the private practitioner invariably plays a critical role in onsite regulatory disease control. In summary, the California EHM regulatory management experience demonstrates that prompt isolation of EHM cases and implementation of baseline premises-level biosafety practices, which are then enhanced upon disease detection, can ensure business continuity and shorter quarantine periods.

Contagious Equine Metritis
In January 2013, a private practitioner evaluating a 17-year-old Lusitano mare with a history of infertility submitted reproductive-tract samples to the California Animal Health and Food Safety Laboratory for bacterial culture. The culture results confirmed presence of *Taylorella equigenitalis*, the organism responsible for the foreign animal disease, CEM. During the 2012 breeding season, the index mare was bred by live cover and artificial insemination to a 20-year-old Brazilian-origin Lusitano stallion imported in 2003. Testing of the Lusitano stallion confirmed infection with *T. equigenitalis*.

The epidemiologic investigation required tracing of any mares or stallions potentially exposed to the infected stallion. An exposed stallion is defined as any stallion collected at the stallion station during the 7 days before the infected stallion and the 7 days after the infected stallion. During the 2012 breeding season, the infected Lusitano stallion was collected at a California stallion station. An exposed mare is defined as any mare bred by live cover or artificial insemination to the infected stallion. The initial epidemiologic investigation identified 11 exposed stallions and one exposed mare. The burdensome testing protocols, at the owner’s expense, included collection intervals of three sets of cultures from exposed mares and stallions and live cover of exposed stallions to two certified CEM-negative test mares. During the testing protocols, the exposed horses were under quarantine and unable to be used for breeding. The stallion station that involved this incident had six exposed stallions onsite; according to the stallion station owner, the estimated loss in revenue during the CEM investigation and quarantine period was $75,000.

One exposed stallion and one exposed mare were subsequently confirmed to be infected with *T. equigenitalis* and underwent required treatment and additional testing protocols. The second infected stallion was a domestic 25-year-old Lipizzaner stallion that had semen collected in 2012 at the same facility as the initially identified infected Lusitano stallion. The second infected mare was a domestic, 13-year-old, Andalusian-cross breed that had been artificially inseminated with semen from the infected Lusitano stallion in 2012. This mare was found to be pregnant. All test positive animals underwent the required additional treatment and testing protocols. The National Veterinary Services Laboratory determined that the strain of the *T. equigenitalis* from all four infected horses were identical but failed to match to any previously identified strains of *T. equigenitalis* from the U.S., indicating these cases were not related to any previous U.S. *T. equigenitalis* cases.

Frozen semen collected in 2009 from the index Lusitano stallion was also confirmed to contain *T. equigenitalis*. The epidemiologic investigation could not determine the time of exposure or source of the infection of this index stallion, given that the private practitioner, who managed the pre-2009 breeding of this stallion in the U.S., had retired and burned his medical records. Fortunately, this incident had limited scope compared with the large multistate outbreak of contagious equine metritis in 2008–2010, which resulted in the detection of 22 *T. equigenitalis*–infected stallions and five *T. equigenitalis*–infected mares at a cost to the industry of $11–16 million.

In summary, an astute private practitioner and laboratory diagnostician detected a foreign animal disease agent and eliminated a potential disease risk to the equine industry. Unfortunately in this incident, the source of infection could not be determined, so continued vigilance is necessary to detect any potentially unidentified carrier animals.

Dual Infection of Racing Quarter Horses With Equine Infectious Anemia and Equine Piroplasmosis Agent
In 2012, the Animal Health Branch of the California Department of Food and Agriculture began investigating infections of EIA and EP in the California racing Quarter Horse population. Since 2012, 39 racing Quarter Horses have been confirmed positive for EIA and 21 racing Quarter Horses have been confirmed positive to *Theileria equi*, the causative agent of EP. Ten of the positive horses had dual EIA and EP infections. One of the dual-infected horses was examined by a private practitioner who had worked with state animal health officials on treating a previously identified *T. equi* infected horse. The private practitioner contacted the SAHO to report that she had examined a racing Quarter Horse that had severe anemia. The
horse’s condition continued to deteriorate and it was euthanized. At time of necropsy, the horse was confirmed to be infected with both EIA and T. equi. Testing of horses from the premises of origin for this horse resulted in subsequent detection of additional EIA and T. equi–infected horses.

The management options for an EIA infected horse are humane euthanasia or restrictive lifetime quarantine of the individual horse at least 200 yards from other horses. All of the EIA-infected horses detected during the 2012 investigation were euthanized. The management options for T. equi–infected horses detected during the 2012 investigation were euthanized. Two of the confirmed T. equi–infected horses successfully completed treatment and were released from quarantine. One EP-positive stallion was unsuccessful in clearance of the organism with two rounds of imidocarb treatment and was subsequently euthanized. Currently, one of the T. equi–infected horses remains under quarantine following two unsuccessful rounds of imidocarb treatment.5 All other T. equi–infected horses detected during this investigation were euthanized.

The epidemiologic investigation into this incident and previous U.S. incidents involving racing Quarter Horses provides useful information for targeting control and outreach efforts to minimize the risk of disease transmission.6 The age range for the California EIA–infected horses was 3–8 years of age with an average age of 4.6 years. The epidemiologic investigation suggests that the majority of the infected horses participated in both sanctioned and unsanctioned Quarter Horses racing in the U.S. Additional aspects of the investigation suggested that cultural practices led to the potential exposure of the affected horses to high-risk practice, such as sharing of needles and other medical equipment or the use of contaminated blood products. Although difficult to verify, information obtained during the investigation suggested potential illegal importation of blood products from Mexico and the illegal movement of racing Quarter Horses across the Mexican border for participation in unsanctioned racing. During the investigation, the Animal Health Branch of the California Department of Food and Agriculture worked closely with California Horse Racing Board (CHRB) resulting in CHRB implementation of EIA testing requirements for all horses entering a CHRB enclosure including those originating from facilities within the borders of California. Although there were fewer cases of EIA in racing Quarter Horses detected in California in 2015, the disease is likely to continue to appear if there are continued high-risk practices occurring among this segment of the industry. Private-practitioner assistance in targeted outreach and education on risks posed by unhygienic practices among the racing Quarter Horse industry population can potentially assist in decreasing exposure of racing Quarter Horses to EIA and other blood-borne infectious agents. It is also important that retired racing Quarter Horses with the potential for exposure to EIA or T. equi be tested and determined to be test negative before moving into their second careers, such as roping, barrel racing, trail, or show uses.

5. Local Role of Private Practitioner on Regulatory Issues
Regulatory officials need private practitioner assistance in addressing equine regulatory issues. The mission is the same for all parties: to protect the health and well-being of the horse. The private practitioners are the eyes and ears in the equine disease world, given that they monitor domestic diseases and likely would be the first to detect potential emergence of foreign animal diseases. Regulatory officials rely on the private practitioner to know what is actually happening disease-wise on horse farms. Practitioners are encouraged to communicate their observations or concerns with regulatory officials. The SAHOs want to know what practitioners are seeing, not just the regulated diseases, but also other health or welfare issues affecting the equine industry. Informed SAHOs can ensure appropriate, feasible, science-based measures can be applied to the situation. SAHOs can be a resource to practitioners to assist with coordinating diagnostic testing, which in some cases may be performed free of charge to the horse owner. For regulatory diseases, the SAHO may have access to research studies related to treatments that may benefit the horse. In addition, the regulatory official may have access to the latest scientific research on new diagnostics or disease control methodologies, which may assist the client in addressing their horse’s disease. Disease agents are ever changing and veterinarians in the field are trying to keep pace. On the national and international equine disease front, regulatory officials continue to monitor diseases of regulatory importance. SAHO may be aware of a disease investigation in the early stages in another state and this information may be beneficial to a veterinarian investigating a similar disease in their practice. However, due to the limited funding and personnel resources, information gathered on diseases of regulatory importance may not be adequately disseminated to the horse industry. The private practitioner can assist by communicating with regulatory officials and sharing the information with their clients. A partnership with two-way dialogue between the regulatory officials and private practitioners ensures that the health and welfare of the horse comes first.

6. Opportunities for Private Practitioner Involvement in Regulatory Issues
Contrary to common belief, decisions regarding equine regulatory issues are not made in a vacuum by regulators sitting in dark rooms. Decisions at
the state and national level are made in consultations with industry stakeholders. Regulators welcome and seek input from private practitioners to ensure regulations and measures appropriately address equine health issues.

At the state level, all SAHOs are interested in hearing from the industry stakeholders. Practitioners are encouraged to contact their SAHO to determine how feedback on equine health issues can be provided in that state. Some states have equine advisory committees that may include private practitioners, whereas other states have industry stakeholder open forums to solicit feedback. Some states may have an e-mail distribution list for notifying practitioners of equine regulatory and any other disease issues, whereas other states with limited resources may rely on private practitioners or state industry representatives to get the regulatory message out to the industry in their state. Making contact with the regulatory official in the state will enable you to become part of the team protecting the health of the horse.

At the national level, several organizations work on equine regulatory issues, such as the USAHA, the National Institute of Animal Agriculture (NIAA), and the American Horse Council (AHC). In addition, national breed or discipline organizations also play a role in protecting equine health by addressing regulatory issues. Private practitioners are encouraged to communicate concerns to these groups.

The USAHA mission is implemented through deliberations of its’ 32 science-based committees and the adoption of resolutions and recommendations aimed at solving animal health problems. The purpose of the USAHA Committee on Infectious Diseases of Horses (IDOHC) is to address and seek solutions to infectious disease issues that can compromise the health of the nation’s equine population. As part of its purpose, the Committee resolves to keep USAHA members, USDA, the equine industry, and other stakeholders informed of disease problems confronting the industry. The committee also serves as a sounding board for discussion on equine health-related issues and for the development of strategies/solutions to resolve such problems. The IDOHC has four disease subcommittees that include a subcommittee on EIA, EP, EHV-1, and CEM. Subcommittees work focuses on using scientific and diagnostic advances to implement new policies and procedures for regulatory disease control. Participation in IDOHC and subcommittee activity is restricted to members of USAHA. To view proceedings of previous IDOHC meetings and accomplishments of the USAHA visit http://www.usaha.org/Portals/6/Committees/horses/IDOHC%20EHV%20Guidance%20Document%20Sept%202015%20Edited%20FINAL.pdf. Those interested in directing regulatory change for equine diseases are encouraged to become a member of USAHA and the IDOHC.

The mission of NIAA is to provide a resource for individuals and organizations to obtain information, education, and solutions for challenges facing the animal agriculture industry. NIAA is dedicated to programs that promote best practices in the management of animal health and wellbeing. The mission of the Equine Committee is to address key equine health issues relevant to the economic wellbeing of the U.S. equine industry. To view proceedings of previous NIAA Equine Committee meetings and accomplishments see http://www.animalagriculture.org. Those interested in discussing equine issues are encouraged to become a member of NIAA Equine Committee.

The USAHA and NIAA co-hosted The Equine Disease Forum on January 19–21, 2016 in Denver, Colorado. The objective of this unique forum was to provide the latest updates on disease threats to equine health, to identify potential solutions for addressing current risks to equine health, and to enhance equine industry collaboration and communications. Those attending the forum included SAHOs, United State Department of Agriculture-Animal and Plant Health Inspection Service-Veterinary Service (USDA-APHIS-VS) veterinarians, and equine industry representatives. The current challenges identified during the forum included limited regulatory funding and personnel, limited federal authority for equine disease control, lack of consistency between states related to disease control and movement regulations, lack of metrics to determine the effect of an equine disease, lack of a centralized equine disease database, limited field-level disease outbreak research, limited traceability of equines, limited implementation of biosecurity, the need for advancing equine practitioner involvement, the potential for stakeholder engagement in disease prevention and control, and the challenges of communication within the equine industry. Next-step discussions focused on four main topic areas: 1) enhancing communications, 2) moving toward consistency in state regulations, 3) implementing an individual equine identification program, and 4) promoting biosecurity. The Forum Planning Committee will review the Forum Evaluation Survey data and feedback to develop a plan for advancing equine health. In addition, a white pa-
per is being prepared for dissemination to stakeholders. For more information about the Forum, including viewing of the presentations, visit www.animalagriculture.org/equineforum.

The AHC was organized in 1969 to represent the horse industry before Congress and the federal regulatory agencies. AHC is a nonprofit corporation that represents all segments of the equine industry. The AHC mission is to promote and protect the equine industry by representing its interests in Congress and in federal regulatory agencies on national issues of importance; to unify the equine industry by informing industry members of regulations and pending legislation, and by serving as a forum for all member organizations and individuals; and to advise and inform government and the industry of the equine industry's important role in the U.S. economy. The AHC Health and Regulatory Committee addresses equine regulatory disease issues. For more information on the AHC membership and activities visit http://www.horsecouncil.org/.

7. Conclusion
Everyone involved with the equine industry has a role in protecting the nation’s equine population and addressing equine regulatory issues. However, the private practitioner plays a vital role in identifying and reporting the occurrence of regulatory diseases, which threaten the U.S. equine industry, to ensure prompt response and immediate control. Communication and cooperation between the equine owning public, private practitioners, industry organizations, and state/federal animal health officials are pivotal for advancing and protecting the health of the nation’s equines.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References
Lessons Learned From Recent Outbreaks of High-Impact Equine Diseases in the United States

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1. Introduction
Recent outbreaks of high-impact equine diseases in the United States during the past few years have highlighted the need for better preparedness, educational outreach, and more direct communication between those responsible for control of equine disease outbreaks and the various facets of the equine industry. An overview of these recent incidents is presented along with key issues identified during the outbreaks and lessons learned for future planning and preparedness.

2. Federal Role in Response to Equine Disease Outbreaks
Regulatory diseases are those diseases that are reportable by law to state or federal animal health authorities. As equine veterinarians, knowledge of regulatory diseases and appropriate recognition and reporting of suspect cases is a key component of our responsibilities. These reportable diseases typically include foreign animal diseases and infectious diseases that are internationally reportable to the World Organisation for Animal Health (OIE), but they also may include other contagious or infectious diseases that have an existing control or eradication program, or potentially any disease that threatens the national herd either by its clinical features or its effect on international trade.

Given that there are many differences between the individual reportable diseases lists of each state, U.S. Department of Agriculture–Animal and Plant Health Inspection Service (USDA-APHIS) recently proposed a National List of Reportable Animal Diseases, which, if codified, might serve to provide a more standardized list which state animal health authorities could reference in their own regulations. Although a specific disease appears on either a state or federal list of reportable animal diseases, it is important to recognize that reportable does not necessarily mean actionable. Although some reportable diseases have a specified response by state or federal animal health officials if the disease is confirmed, other diseases may have been made reportable due to the need for surveillance data to be collected or reported and not necessarily because some sort of movement restriction or other response action will result if that disease is found.

When a reportable disease that is actionable is identified, often state and federal animal health officials collaborate in their response to that particular disease. Although federal animal health authority does provide for the issuance of a federal...
quarantine, in most cases this is not necessary and we tend to jointly respond to regulatory diseases using the state’s quarantine authority. Some of the resources that the federal animal health authority (USDA-APHIS–Veterinary Services) brings to a response effort include field personnel, such as veterinary medical officers and animal health technicians, laboratory diagnostic support through the National Veterinary Services Laboratories and the National Animal Health Laboratory Network, subject matter experts and epidemiological support, and trade support and negotiation. Overall, it is the quick identification and rapid response involving strong collaboration between state animal health officials, federal animal health officials, private practitioners, academia, laboratories, and the equine industry that results in the most successful responses to regulatory disease outbreaks.

3. Recent High-Impact Equine Disease Outbreaks

A “high-impact” or “high-consequence” equine disease is a disease that has one or more of the following characteristics:

- Results in high morbidity or high mortality
- Has the potential for human health implications
- Is listed as a foreign-animal disease
- Domestic disease with new increased/unexpected virulence
- Disease with limited intervention options
- Disease that has severe or debilitating trade ramifications
- Results in an outbreak that affects a large number of equids/owners/premises
- Any disease that elicits a palpable level of concern or panic in the equine industry

Unfortunately, the United States has experienced a number of equine disease outbreaks in recent years that could be considered to fit into this “high-impact” category. The following includes summary information and lessons learned on some of the most significant high-impact equine disease outbreaks encountered.

4. Contagious Equine Metritis

In December 2008, an active breeding stallion in Kentucky was found to be culture positive for *Taylorella equigenitalis*, the causative agent of contagious equine metritis (CEM), when he was sampled to qualify for semen export. Given that CEM is a foreign-animal disease in the United States, an extensive regulatory investigation ensued during the next 2 years in which 1005 horses (278 stallions and 727 mares) were determined to have been directly exposed in 48 states. Diagnostic testing of the exposed horses eventually led to the finding of 22 stallions, one gelding, and five mares being chronic carriers of *Taylorella equigenitalis* at the time they were tested.

It is likely that many more mares may have actually become infected immediately after their exposures to positive stallions in the outbreak; however, due to the ability of many mares to clear the infection on their own with only a small percentage resulting in a chronic carrier state, it is unknown just how many mares were actually previously infected in the incident. Epidemiologic analysis suggested that all of the positive horses were linked to a single common source, most likely a Fjord stallion imported into the United States in 2000. The investigation also showed that stallion-to-stallion transmission occurred through contaminated fomites at breeding facilities such as inadequately cleaned and disinfected artificial vaginas, wash buckets, breeding dummies, hands, or other sources. Transmission to mares occurred through both live-cover breeding and artificial insemination even when semen extenders containing seemingly appropriate antibiotics were used.

All exposed horses were quarantined and could not be used for breeding activities until completion of the regulatory testing protocol yielded all negative results. This was an expensive process especially for stallion owners given the official protocol, based on our rigorous U.S. CEM-import protocol, required test breeding of two qualified mares and a sampling period over approximately 30 days to be completed. Although some cost sharing was provided in which USDA-APHIS covered the cost of the sample shipping and diagnostic testing and state animal health officials provided personnel resources and oversight, the exposed horse owner had to cover the cost of sample collection by their private practitioner. This burden ended up being cost prohibitive for some stallion owners at the time and those stallions were forced to stay under quarantine until the sampling and testing could be completed.

All of the infected horses were ultimately successfully treated, confirmed as negative on retesting, and released from quarantine with the response to the incident completed in late 2010. Although this outbreak was the largest CEM outbreak in U.S. history both in geographic scope and numbers of horses involved, other smaller outbreaks of CEM have occurred since with most cases traced back to some involvement with previously imported horses. This leaves concern as to how imported horses infected with *T. equigenitalis* are slipping through our import-testing protocols and whether exemption from CEM testing on horses imported from certain countries might be contributing to the problem. In addition, as was the case in the 2008–2010 outbreak, most of the subsequent index-infected stallion cases in the United States were identified on routine culture for qualification to export semen to another country. The absence of adequate domestic surveillance for *T. equigenitalis* in the U.S. active breeding stallion population almost guarantees that CEM cases will not be detected quickly and, therefore, may eventually lead to another outbreak of size...
and scope similar to that seen in the 2008–2010 incident.

Lessons learned from recent CEM outbreaks include the following:

- Despite CEM quarantine and rigorous testing for imports, outbreaks in the United States can and do occur.
- Many different breeds and disciplines can be affected in CEM outbreaks (there were 12 breeds of stallions found to be infected in the 2008–2010 outbreak).3
- The sheer volume and frequency of equine movements leads to continued spread in the absence of adequate biosecurity.
- CEM testing of >1000 horses in 48 states, as happened in the 2008–2010 outbreak, is challenging and expensive for all involved.
- Even foreign-animal diseases require good domestic surveillance to detect.
- Education and outreach to the equine industry needs to be an ongoing effort, especially on the topics of biosecurity in breeding practices and maintaining surveillance in active breeding stallions.

5. Vesicular Stomatitis

Although vesicular stomatitis (VS) is a seasonal, sporadically occurring endemic disease in the southwestern United States with large-scale outbreaks typically surfacing every 8–10 years, the trade ramifications associated with these outbreaks can be crippling to the equine industry. When outbreaks occur, any VS-susceptible livestock, including horses, in an affected state are barred from movement to Canada until 21 days after the last quarantine in that affected state is released. Given that VS outbreaks can go on from early spring through the fall and sometimes even into early winter, movement of horses from the United States to Canada or even attempts to return Canadian horses to Canada can be extremely challenging. In addition, many other countries impose VS export testing requirements on all susceptible United States livestock, which is an added cost to the export process. Horses exposed to vesicular stomatitis virus (VSV) during an outbreak year can maintain antibody titers for many years thereafter, which may effectively remove their eligibility for export if a country requires a negative VSV antibody test for importation. Finally, more rigorous interstate movement requirements during an outbreak or concern for disease exposure can cause equine event participants to be unable or unwilling to attend an equine show or event in a VS-affected state, which can have a serious economic effect on the event, the venue, and the state.

Back-to-back VS outbreaks in 2014 and 2015 involving the same strain and genetic lineage of VSV resulted in all of these described economic hardships and challenges. The 2014 VS outbreak was the largest in the United States since 2005, occurred from May 23, 2014 to March 13, 2015, and required a considerable joint state and federal regulatory response to manage. Although a total of 435 VSV-positive premises (New Jersey serotype) were confirmed in four states; Arizona (two premises in one county), Colorado (370 premises in 17 counties), Nebraska (one premises in one county, and Texas (62 premises in 13 counties), many more suspect and presumptive-positive premises were also quarantined and managed during the response. Of the 435 confirmed infected premises, 405 were positive equine premises, 27 were positive bovine premises, and three premises had both cattle and horses positive.4 A change to the state/federal response to VS occurred between the 2014 and 2015 outbreaks when the OIE voted to remove VS from the international list of immediately reportable diseases.

In discussion between state and federal animal health officials on what modifications to the existing response might be appropriate in light of OIE’s delisting of the disease, the following key conclusions were reached:

1. VS-control strategy is still needed to prevent movement of infectious animals and to secure both interstate and international trade during an outbreak.
2. VS must remain reportable to state and federal officials to implement this control strategy.
3. Although existing regulatory response protocols in cloven-hooved species must be maintained to rule out other diseases such as foot-and-mouth disease, response to equine cases can be appropriately modified to reduce the effect on state and federal resources.

Based on these conclusions and other recommendations, state and federal officials employed a modified response in the 2015 VS outbreak. New measures included a reduction in the quarantine period based on viral shed from affected animals, activation of VS-approved National Animal Health Laboratory Network laboratories to assist in testing of affected equine species, and flexibility to use accredited veterinarians for sample collection in equine species and management of affected equine premises.

These key changes to the response were timely indeed, as the 2015 VS outbreak quickly broke all records and emerged as the largest VS outbreak in recent history with a total of 823 affected premises in eight states: Arizona (36 premises in three counties), Colorado (441 premises in 36 counties), Nebraska (38 premises in 10 counties), New Mexico (52 premises in 13 counties), South Dakota (50 premises in seven counties), Texas (four premises in four counties), Utah (56 premises in 8 counties), and Wyoming (146 premises in 10 counties).5 With approximately 90% of the 823 affected premises being equine premises, involvement of private practitio-
The epidemiology investigations conducted

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in all of these cases have indicated no evidence of tick-borne transmission and the cases in racehorses, specifically, have involved iatrogenic transmission (needle/syringe/IV equipment reuse, blood transfusions, contamination of multi-use drug vials, etc.) as the method of spread. There were also epidemiological links to unsanctioned racing found in many of these cases.

Although active surveillance for EP through testing to enter sanctioned racetracks has been highly successful in identifying infected Quarter Horse racehorses, a disturbing trend has appeared as the number of tracks requiring testing has decreased during the past 6 years. There were more than 75,000 horses tested annually through all active U.S. surveillance in 2010 and 2011 and more than 45,000 horses tested in 2012, but surveillance testing has declined over time to only 20,000 horses tested in 2015. Although there was once at least 11 states that required EP testing to enter sanctioned racetracks, at the time of this writing only two states (Texas and New Mexico) currently have a standing EP test requirement for entry to racetracks. In addition, 14 of the 15 T. equi-positive Quarter Horse racehorses identified in 2015 had been running exclusively at sanctioned tracks that had removed their previous EP test requirement and these horses were only found positive when the index case in each cluster was tested to enter a Texas racetrack.

All EP-positive horses found in the United States are placed under State quarantine and the horse owners are offered four options for long-term management under state/federal regulatory oversight: 1) life-time quarantine, 2) euthanasia, 3) export from the country, or 4) long-term quarantine with enrollment in the APHIS-VS and USDA-Agricultural Research Service treatment program using a published high-dose imidocarb dipropionate protocol. In February 2013, APHIS-VS established a policy to release horses previously infected with T. equi that had completed the official treatment program, been proven cleared of the organism by a series of diagnostic methods over time, and were test negative on all available diagnostics. Of the 262 positive horses unrelated to the Texas ranch outbreak, 162 have either died or been euthanized, 18 have been exported, and 55 have been enrolled onto the treatment research program. Twenty-six of the horses enrolled onto the treatment program have met all of the test-negative requirements and have been released from quarantine. From the Texas ranch outbreak, 163 horses were enrolled onto the treatment research program and have completed treatment with more than 140 horses having met all test-negative requirements and are eligible for release.

Over the past few years, during investigation of T. equi-positive Quarter Horse racing clusters, 13 horses that were co-infected with EIA virus were identified in three different states. In all of these cases, iatrogenic transmission of both T. equi and EIA virus was implicated as the cause of the dual infections. It seems clear that the unhygienic practices occurring in these high-risk groups of horses have the propensity to spread all blood-borne pathogens and it is as-yet unknown how widespread these practices might be. These recent findings have led to a change in regulatory follow-up testing. Whenever an EP or EIA-positive Quarter Horse racehorse is identified, regulatory officials have instituted testing for the other disease as well to evaluate whether the horse may be co-infected with the other pathogen.

Quarter Horse racehorses have also been unexpectedly involved in large clusters of EIA-positive cases found during the past few years. Thirty-nine EIA-positive Quarter Horse racehorses were found in California between 2012 and 2015, and a single epidemiologically-linked cluster of at least 15 EIA-positive Quarter Horse racehorses were found in California, Oregon, and Washington in 2015 alone. Iatrogenic transmission related to owner/trainer practices was indicated as the most likely cause in the majority of these cases. It seems that the historic absence of an EIA test requirement for “in-state” horses to enter racetracks in California, Oregon, and Washington may have played a role in some of these cases having gone undetected for so long.

Lessons learned from these EP and EIA outbreaks described include the following:

- EP has been identified in three distinct populations in the United States: the isolated Texas ranch incident, which has since been resolved; horses imported prior to 2005; and the Quarter Horse racing industry.
- Natural tick-borne transmission of EP in the United States is likely to be sustained and efficient only in certain geographic areas if the disease is allowed to exist in horses there.
- EP and EIA transmission via iatrogenic means is an ongoing problem in the Quarter Horse racing industry, especially in the horses, owners, and trainers with ties to unsanctioned racing.
- Surveillance testing and educational outreach in high-risk equine populations is the most effective way to mitigate iatrogenic spread of the causative agents of EP and EIA.
- Treatment continues to be a promising exit strategy for horses infected with the causative agents of EP.
- Surveillance testing for EP in Quarter Horse racehorses has been declining in recent years and may not be adequate to find positive horses before they move to other sectors of the industry.
7. Equine Herpesvirus Myeloencephalopathy

One of the largest equine herpesvirus myeloencephalopathy (EHM) outbreaks in North America occurred in horses that had attended the National Cutting Horse Association Western National Championship held April 29 to May 8, 2011 in Ogden, Utah. Although EHM is not a federally reportable disease and is only variably reportable in selected states, due to the multistate nature of this outbreak, the American Association of Equine Practitioners, the American Horse Council, and the National Assembly of State Animal Health Officials requested assistance from USDA-APHIS-Veterinary Services in coordinating and communicating the outbreak response.

The initial EHM cases that presented subsequent to leaving the event were quickly determined diagnostically to be infected with the neuropathogenic strain type of EHV-1. With more than 400 horses officially entered in the event and an undetermined number of tag-along, turn-back, and noncompeting horses in training all disburse to 19 potential destination states, it was clear that the total number of primary exposed and secondary exposed horses was going to be extensive. In fact, the total number of horses and premises exposed could never be determined, but was confirmed to have been more than 2100 horses exposed on more than 240 premises in 19 states. By the end of the outbreak on June 23, 2011, a total of 57 EHV-1 cases and 33 EHM cases were confirmed on 62 premises. Thirteen horses died or were euthanized in association with the outbreak. Although these cases represent exposed horses that presented with clinical signs and had laboratory confirmation of EHV-1, there were many more suspect cases that had no laboratory confirmation and therefore were absent from these final statistics. An additional 66 horses were EHV-1 suspect cases and 10 horses were EHM suspect cases with no laboratory confirmation.

As state animal health officials scrambled to find the exposed horses, set up either voluntary or official movement restrictions, and implement biosecurity and containment on exposed premises in the initial days of the outbreak, the social media exploded with misinformation and caused additional panic across the equine industry. Although the misinformation was eventually overcome through national-level situation reporting on the USDA-APHIS website and clear, concise guidance by the National Cutting Horse Association and American Association of Equine Practitioners, the outbreak had revealed the ugly side of social media during a disease outbreak. This has led directly to the creation of the equine disease communication center (EDCC), an equine industry initiative with collaborative support from state and federal animal health officials and many equine organizations within the industry. The goal of the EDCC is to ensure that confirmed equine disease outbreak information is being quickly gathered and reported to the general public to avoid the spread of misinformation. It also provides one-stop-shopping for general disease information and reliable sources for guidelines on disease control and biosecurity. The EDCC’s involvement in dissemination of information in more recent EHM outbreaks has seemingly greatly reduce the amount of misinformation being spread through social media.

Lessons learned from recent large-scale outbreaks of EHM include the following:

- Frequent and widespread movement of horses in the United States is a continued risk factor for significant EHM outbreaks.
- Biosecurity at both the individual horse and individual premises levels is the most important method of prevention of disease spread.
- Widespread education and outreach within the equine industry is needed to help horse owners, trainers, event organizers, and equine facility managers understand and implement appropriate biosecurity to prevent spread of EHV-1.
- During an EHM outbreak, there is a need for immediate transparency, notifications, clear guidance, and updated public information on the outbreak to inform decision making at all levels.
- Differences between states on reporting and response measures for EHM have been a challenge to adequate response and prevention of disease spread.
- Equine practitioners have the unique expertise and opportunity to provide consultation to equine owners and event managers on biosecurity protocols and infection control planning.

8. Conclusions

Although the responses to outbreaks of CEM, VS, EP, EIA, and EHM have been generally successful in recent years, there have been critical lessons learned in each of these incidents. Some of the incidents have highlighted key weaknesses in our ability to prevent disease introduction, surveillance strategies that need to be bolstered, or high-risk populations that need more targeted efforts. There are a number of overarching themes that can be garnered from each of these experiences. First, the structure of the equine industry itself can be a challenge to disease control in that it is vast, highly segmented, composed of individuals with varying levels of awareness and knowledge about infectious disease, and unmatched in the sheer volume and frequency of horse movements. Given these characteristics, there is a need for educational outreach on infectious disease and biosecurity for the newest members of the industry up to and including the most experienced members of the equine industry and via a variety of outreach methods. There is a need for planning and preparedness for equine disease outbreaks throughout all levels of the industry,
from the individual horse owner to the facility manager to the event organizers and beyond. There is a responsibility of all involved in disease outbreaks to communicate and share accurate information in a timely manner. Finally, there is a clear need for more direct interaction between equine industry groups, equine practitioners, and state/federal animal health officials to prepare for and respond to equine disease threats in the United States.

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Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Author declares no conflicts of interest.

References
Evaluation of Biofilm and the Host Immune Response Using an Experimental Model of Bacterial Endometritis

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Pseudomonas aeruginosa is capable of producing a biofilm in the uterus, the host immune response is reduced in areas with biofilm, and Bouin’s solution is more appropriate for detecting material adherent to the endometrium. Authors’ addresses: Departments of Clinical Sciences (Ferris, Hennet, McCue), and Microbiology, Immunology and Pathology (G. Borlee, B. Borlee), Colorado State University, Fort Collins, CO 80523; e-mail: ryan.ferris@colostate.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Bacteria can produce a biofilm matrix to become more tolerant of antimicrobial treatment.

2. Materials and Methods
Six mares were inoculated with Pseudomonas aeruginosa modified to express a luminescent gene. Following establishment of the infection the horses were euthanized, the uterus was opened, and the endometrial surface was rinsed with lactated Ringer’s solution pressurized through a 20-gauge needle. The endometrial surface was imaged for luminescence to localize adherent labeled bacteria. Samples from areas of endometrium were collected for cytology, histopathology, carbohydrate analysis, and gene expression of inflammatory cytokines.

3. Results
Adherent bacteria were present in focal areas between endometrial folds (6/6 mares). The biofilm exopolysaccharide Pel (5/6 mares) and cyclic di-guanosine monophosphate (6/6 mares) were detected in endometrial samples only with adherent bacteria (P < .05). A greater (P < .05) incidence of adherent material was present in samples fixed in Bouin’s solution (18/18) as compared to buffered formalin (0/18). There were no differences (P > .05) in the inflammatory cells in the endometrium or gene expression for ten host inflammatory genes. There were decreased (P < .05) neutrophils in areas with adherent material (0–2 white blood cells per high power field).

4. Discussion
A biofilm was identified in all in vivo experimental cases of equine endometritis that resembles biofilm associated infections in human medicine. Future studies will focus on therapeutic options for elimination of bacterial biofilm in the equine uterus.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Funding Sources
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A Prospective Case-Control Study of Biomarkers for Feto-Placental Well-Being in the Mare

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Decreased serum estradiol and increased serum alpha fetoprotein concentrations in pregnant mares during late gestation were associated with abnormal pregnancy outcome. Authors' addresses: Gluck Equine Research Center (Wynn, Ball, Fedorka, Troedsson, Squires), Veterinary Diagnostic Laboratory (Kennedy), and Department of Obstetrics and Gynecology (Curry), University of Kentucky, Lexington, KY 40546; Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois–Urbana-Champaign, Urbana, IL 61802 (Canisso); Division of Comparative Pathology, Miller School of Medicine University of Miami, Miami, FL 33136 (Cray); e-mail: b.a.ball@uky.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Better diagnostic markers for feto-placental well-being are desirable for equine pregnancy, and recent studies have indicated that estradiol-17β, progesterone, alpha fetoprotein (AFP), and serum amyloid A (SAA) may be useful as indicators of normal pregnancy in mares. The objectives of the current study were to examine changes in these biomarkers in mares with normal and abnormal pregnancy outcomes.

2. Materials and Methods
Mares (n = 700) had blood samples taken on a weekly basis beginning in December through parturition or abortion. Mares (n = 15) aborting or presenting placental lesions at delivery had their placentas submitted for pathologic examination. A group of gestationally age-matched mares (n = 30) had placentas submitted and were used as controls. Estradiol-17β, progesterone, AFP, and SAA concentrations were determined by immunoassay in the sample preceding abortion/parturition in case mares as well as samples from the matched control mares. Data were analyzed using nominal logistic regression.

3. Results and Discussion
Diagnoses included umbilical cord lesions (n = 2), equine herpesvirus 1 (n = 1), idiopathic abortion (n = 3), nocardioform placentitis (n = 2), bacterial placentitis (n = 5), and premature placental separation (n = 2). Median gestational age of case mares was 329 days (range, 246–355 d). For the single serum sample taken within 1 week prior to abortion or parturition from case mares, AFP was positively (P < .01), estradiol-17β was negatively (P < .01), and SAA tended (P < .1) to be positively associated with abnormal pregnancy outcomes. In contrast, a single deter-
mination of progesterone was not significantly associated with pregnancy outcome. This study suggests that decreases in estradiol concentrations relative to control mares and elevations in AFP concentrations, within 7 days of parturition or abortion, may be useful in predicting abnormal pregnancy outcomes during late gestation based upon a single serum sample.

Acknowledgments
Supported by the Albert G. Clay Endowment of the University of Kentucky. The authors acknowledge the support of numerous veterinarians and farm personnel in obtaining the samples used in this study.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Retrospective Study on the Effect of Sperm Number, Number of Artificial Insemination per Cycle, Timing of AI, and Site of AI on Pregnancy Rates With Frozen Stallion Semen

David B. Scofield, DVM, MS, DACT*; Julie B. Skaife, PhD; Barry A. Ball, DVM, PhD, DACT; Sandro Barbacini, DVM; Edward L. Squires, PhD; and Paul Loomis, MS

Based on data from a large multicenter study, pregnancy rates with frozen semen were increased when sperm numbers inseminated increased from 400 to 800 million total sperm and mares were inseminated more than once per cycle. Pregnancy rates for mares inseminated using deep-uterine-horn artificial insemination (AI) were similar to uterine-body AI. Authors' addresses: Gluck Equine Research Center, Department of Veterinary Science, University of Kentucky, Lexington, KY 40546 (Ball, Squires); Select Breeders Service, Inc., Chesapeake City, MD 21915 (Scofield, Skaife, Loomis); SBS-Italia, Medesano, Parma, Italy (Barbacini); e-mail: davidscofield@selectbreeders.com. © 2016 AAEP.

1. Introduction

Limited data are available on the effect of sperm number, site of sperm deposition, number of artificial insemination (AI), timing of AI, and site of sperm deposition on fertility of frozen semen. Objectives were to use data from a large retrospective study to determine the effects of sperm numbers, the number of AI per cycle, timing of AI, and the site of AI (uterine body vs horn) on pregnancy rates of frozen/thawed semen.

2. Materials and Methods

Mares were inseminated with frozen semen on 1169 mare cycles from 168 stallions. Data were analyzed using a logistic regression with repeated measures, adjusting for sperm numbers inseminated.a

3. Results and Discussion

The odds of a pregnancy were 1.52 times greater for those inseminated with 800 million total sperm vs 400 million and 1.25 greater when mares were inseminated more than once per cycle. Timing of AI with frozen semen, either before ovulation, before/after ovulation, or strictly post ovulation, did not affect pregnancy rates. Site of frozen semen deposition did not affect pregnancy rate per cycle (P = .72). In summary, using higher sperm numbers and multiple AI per cycle increased pregnancy rates with frozen semen, but pregnancy rates did not increase with deep-horn AI.

Acknowledgments

Drs. Scofield, Skaife, Barbacini, and Loomis are affiliated with Select Breeders, Inc., and data for this

Research Abstract—for more information, contact the corresponding author
study was obtained for semen produced from our laboratories so that accurate sperm numbers were used.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Footnote
Efficacy of Mechanical Versus Non-Mechanical (Active Versus Passive) Sterile Preoperative Skin Preparation With Chlorhexidine Gluconate 4% Solution

Benjamin I. Davids, BS*; Megan J. Davidson, BS; Saundra H. TenBroeck, PhD; Patrick T. Colahan, DVM, DACVS; and Monika W. Oli, PhD

Chlorhexidine gluconate 4% solution, applied and left to sit for 5 minutes, achieves equivalent skin antisepsis compared with a traditional 5-minute scrub. This technique also reduces the cost of preparation by 68%, making it more economical for practitioners. Authors' addresses: Department of Animal Sciences (Davidson, TenBroeck), Department of Microbiology and Cell Sciences (Oli), College of Veterinary Medicine (Colahan, Davids), University of Florida, Gainesville, FL 32611; e-mail: b.davids92@gmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Adequate skin antisepsis is an important part of any invasive procedure. Previous research has suggested that scrubbing is not necessarily advantageous for antisepsis. We compared a passive paint-on preparation to an active scrub preparation with chlorhexidine gluconate 4% solution (CG). We also compared relative costs of the two techniques.

2. Materials and Methods
For the active scrub technique, CG was applied focally to the center of the preparation area and spiraled outward for 75 s, then wiped with sterile saline for 25 s and repeated twice more for a total time of approximately 300 s. For the passive preparation, CG was applied in the same fashion, not to exceed 15-second scrub time, left on the skin for approximately 255 s, then rinsed with sterile saline for a total preparation time of approximately 300 s. Skin-swab cultures were taken at intervals.

3. Results
The active and passive preparations significantly reduced surface bacteria compared with samples taken from unprepared skin ($P < .05$). No difference in the number of skin-associated bacteria was detected between the techniques ($P = .77$). Cost analysis determined there was a 67.8% decrease in total cost with the passive technique.

4. Discussion
Active and passive skin preparations with CG were equally effective in reducing bacterial contamination of the skin. The passive method

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NOTES
required less technician time, fewer supplies, and was less expensive.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

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How to Perform Ultrasound Guided Intra-Articular Analgesia of the Cervical Articular Facets

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1. Introduction
Osteoarthritis of the equine cervical facets can be associated with stiffness, a reluctance to bend or collect, pain on palpation, and forelimb lameness. In cases of forelimb lameness, the cervical region may become an area of suspicion as the source of lameness if the patient fails to respond to regional and intra-articular diagnostic analgesia of the affected limb, and/or the patient exhibits other clinical signs of neck pain. At this point, the patient will often undergo further diagnostic imaging, including nuclear scintigraphy, cervical radiography, and cervical ultrasound.

Even with an abnormal diagnostic imaging finding in the cervical region, the clinical significance is often unknown, and this does not necessarily indicate a source of pain. Although it is commonplace to correlate diagnostic imaging findings in the limb with results of regional and/or intra-articular analgesia to assess clinical significance, this combination of diagnostics is less routinely performed in the axial skeleton. In many cases, empiric treatment is used based on the results from imaging modalities, and response to treatment is used to confirm or deny the source of pain. Although less commonly performed, ultrasound-guided intra-articular analgesia can be used to more accurately identify the source of a forelimb lameness associated with the cervical spine.

2. Anatomy
The articular facets are composed of the caudal articular process of the more cranially located cervical vertebra and the cranial articular process of the caudally located vertebra (Fig 1). The facets vary somewhat in size and shape, depending on anatomic location. The caudal articular processes of C6 are...
shorter and thicker compared with the same processes on the more cranial vertebrae. The cranial articular processes of C7 are also wider and longer than its caudal articular processes. This gives C6–C7 a characteristic more rounded, prominent appearance than the adjacent articular facets. Ultrasonographically, C6–C7 is usually located just cranial to the slope of the shoulder. The ability to visualize C7–T1 varies, and in horses with longer, thinner necks, it may be readily visualized; whereas in horses with shorter necks, C7–T1 may not be visible beyond the shoulder.

The ventral branches of the last three cervical nerves and the first two thoracic nerves contribute to the brachial plexus, with the primary component coming from cervical nerves seven and eight and thoracic nerve one. The sixth cervical nerve exits the foramen at C5–C6, the seventh cervical nerve at C6–C7, and the eighth at C7–T1. Thus, nerve root compression would most likely contribute to forelimb lameness from these locations. However, lesions more cranial in the cervical spine have also been associated with forelimb lameness, and site selection need not be limited to these more caudal facets.

3. Materials and Methods

Step 1: Identify the Site for Diagnostic Analgesia
Diagnostic imaging findings and the clinical examination should be correlated in selecting the site(s) for diagnostic analgesia. In cases that have undergone scintigraphy, increased radiopharmaceutical uptake of one or more cervical facets may help in site selection. Radiographic abnormalities associated with abnormal cervical facets include osteoarthritis, enlargement and modeling, narrowing of the intervertebral foramina, fracture, and osteochondrosis. Ultrasound evaluation of the cervical spine is also recommended in most cases. Ideally the ultrasound evaluation should be performed subsequent to radiography, given that radiography can improve lesion identification on ultrasound.

Many times when intra-articular medication of facet joints is used, more than one articular facet is treated. Although this may be helpful from a therapeutic standpoint, it limits the specific diagnostic value of assessing response to treatment. For this reason, performing a single site at a time is recommended for diagnostic intra-articular analgesia of the cervical facets. If the patient does not respond to diagnostic blocking at that site, the process can be repeated at the next location of greatest suspicion. Doing a single site at a time also minimizes any potential risk of paresis if the block affects the nerves that contribute to the brachial plexus.

When the articular facet has been selected via the diagnostic imaging findings and clinical examination, it should be definitively identified via ultrasound prior to injection. To ensure the proper location, the scan should begin from C2, counting caudally to locate the facet of choice. The site can then be marked with white tape or white correction fluid. If clipping is permitted, a small square can be clipped at the site of needle placement to further localize the site.

Step 2: Preparation
Preparation is the same as for ultrasound-guided medication of the cervical articular facets and has been previously described in detail. If the patient has a sleek haircoat, clipping is not necessary. Otherwise, a small section should be clipped for the site of needle placement, and, if necessary for image quality, a larger section for better contact of the ultrasound probe. Because the site of needle placement will vary depending on the horse’s head position, a generous area should be prepared with aseptic technique.

Prior to aseptically preparing the area of injection, the ultrasound machine settings should be arranged for maximum image quality, minimizing the need for image manipulation at the time of the injection. We prefer to use a linear probe to maximize image resolution, but a micro or macro convex probe can be used, if necessary (Fig 2). The depth should be set so that the facet is centered in the image, and the gain and frequency should be at a level that maximizes image quality. After the machine is set, the skin can be prepared routinely for injection. The ultrasound probe should be covered with a sterile glove or sterile probe cover with gel placed inside.

For intra-articular analgesia of the cervical facets, we limit the volume of mepivacaine to 2–3 mL. Although the cervical facet joints can reportedly...
be distended with up to 20 mL of fluid, there is increased risk of extravasation with increasing volume. In an unpublished cadaver study of ultrasound-guided intra-articular contrast evaluated with computed tomography, we found increased risk of extravasation of volumes greater than 6 mL. However, it should be acknowledged that volume of 2–3 mL is an empirically selected dose and has not directly been compared with other amounts. A larger volume of 8–10 mL has also been used by another experienced clinician with no reported complications.

Because the lameness examination will continue after analgesia, no sedation is used. A nose twitch is applied for restraint. Often, horses will raise their heads with the application of the twitch. It is important to keep in mind that this change in head height will alter the position of the cervical facets and injection site, further emphasizing the importance of a large prep area for injection. We do not routinely use local anesthetic of the skin prior to injection because the location for needle placement can change depending on head position and also because most horses do not significantly object to needle placement.

Step 3: Injection
Although both longitudinal and transverse approaches to cervical facet injections have been described, we prefer the transverse approach. The injection technique is the same as intra-articular medication of the cervical facets. The transducer is placed in a transverse plane to the long axis of the cervical facet, with the probe marker oriented at approximately 11 o’clock. The handle of the transducer can be kept in a neutral position or lowered slightly ventrally, which helps align the joint space and the trajectory of the needle (Fig 3). An 18-g or 20-g, 3.5-inch spinal needle is used for the injection. The needle is placed at the dorsal aspect of the probe and should be angled toward the joint space, which is centered in the image. The exact angle will vary depending on how the facet is positioned in the image but typically ranges from 30 to 45 degrees from the horizontal plane. A common error is to

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**Fig. 2.** Transverse ultrasound images of a cervical articular facet. Dorsal is to the left. The image resolution is superior using the linear ultrasound probe (A) when compared with the macroconvex ultrasound probe (B) at the same depth. The joint space is denoted by the arrows.

**Fig. 3.** Transverse ultrasound images of a cervical articular facet. Dorsal is to the left. Image A is obtained in neutral position. In image B, the handle of the probe is lowered slightly ventrally, displacing the joint space dorsally on the ultrasound image. This dorsal position can facilitate aligning the needle trajectory with the joint space in some cases. The joint space in denoted by the blue arrows.
insert the needle at too steep or too flat of an angle and pass the joint space (Fig 4).

Once the needle is placed at the margin of the joint space, the stylet is removed and the syringe applied. It is important that the ultrasound probe be kept in place during the entire process to ensure that the needle placement is not altered. The needle should not move deep to the peri-articular margin. Ideally, a second person will attach the syringe while the other person holds the needle and ultrasound probe in place; although, if necessary, a single operator can perform the entire procedure. We do not routinely aspirate joint fluid; to confirm needle placement, a small test injection should be performed and observed on the ultrasound screen to ensure that the fluid is entering the joint and that there is no evidence of peri-articular injection or extravasation. When needle placement is confirmed, the remainder of the mepivacaine can be injected, with the entire process being evaluated on the ultrasound image to ensure that the fluid is within the joint recess. As the fluid enters the joint, the joint capsule should be seen expanding away from the bone margins.

Step 4: Evaluation

After the injection, we prefer that the horse be walked to a well-bedded or padded stall. Although we consider the risk of paresis to be quite low if only one facet is blocked at a time, we operate with an abundance of caution. After 10 minutes, the horse is usually evaluated at a walk and a trot. A repeat evaluation can be performed at 20 minutes. If the lameness is not alleviated or resolved with the intra-articular analgesia, the process can be repeated if there is another site of clinical suspicion.

4. Results

Since we began performing this procedure in 2013, we have used this technique in six horses. All horses were Warmblood breeds and ages ranged from 5 to 17 years of age. We have experienced no significant complications, including no evidence of weakness or paresis. Four of the horses exhibited unilateral forelimb lameness, one had a history of stumbling and falling under saddle, and the sixth horse exhibited a stiff neck and decreased performance prior to the procedure. The four horses with forelimb lameness underwent extensive diagnostic blocking of the affected forelimb prior to electing to perform intra-articular analgesia of the cervical facets. All horses had some degree of modeling or osteoarthritic changes of at least one articular facet on diagnostic imaging evaluation, although, in no cases were the changes found to be severe. Two horses had only one location blocked, two horses had two locations blocked at two different time points, and one horse (history of stumbling) had four locations blocked at different time points.
The four horses with forelimb lameness as the primary complaint responded to blocks as follows: Horse 1 exhibited 75% improvement within 15 minutes following block of the second site (no response to the first site). Horse 2 improved 60% after the first block. Horse 3 improved 40% with further improvement to 80% of the lameness with an abaxial nerve block (although previously the horse had not improved with an abaxial block prior to the cervical facet block). Horse 4 had an unusual stride characteristic that improved after diagnostic analgesia of the cervical facet, but the lameness persisted. The horse with a history of neck stiffness and poor performance had improved movement after diagnostic analgesia. No improvement was noted in the horse with a history of stumbling.

5. Discussion
Diagnostic analgesia of the cervical facets should be considered in cases of forelimb lameness that cannot be attributed to other locations in the limb. In addition, it can be used in cases of neck stiffness or poor performance, although change may be more difficult to assess in horses with subtle clinical signs. Although medical therapy can be used as both a diagnostic and therapeutic procedure, diagnostic blocking may identify a more specific source of the lameness and may also eliminate unnecessary treatment in horses that are unresponsive to diagnostic blocking. Although it is possible for a horse to have pain originating from locations in the neck, such as from the vertebral body, that would not likely respond to analgesia of the articular facet, the screening performed by the diagnostic imaging can help target which horses have pathologic changes associated with the articular facet rather than elsewhere in the cervical region.

The injection technique is quite similar to intra-articular medication of the cervical facets, with the primary complicating factor that the patient is not sedated. Watching the injections in real time on the ultrasound screen minimizes the risk of improper needle placement and the low volume of fluid leads to a low risk of extravasation. Performed in this manner, we believe this of similar safety as intra-articular diagnostic analgesia of other joints.

In summary, we have had successful outcomes using ultrasound guided intra-articular diagnostic analgesia of the cervical articular facets for identifying the source of forelimb lameness. This technique is an additional tool that can be used in the workup of forelimb lameness or other abnormalities associated with neck pain. For practitioners already experienced in performing therapeutic ultrasound guided intra-articular injections of the cervical articular facets, the technique is easily applied and can be performed safely.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

References and Footnotes

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*Dyson, S. Newmarket, Suffolk, 2016 (personal communication).*
How to Perform Dorsolateral Arthrocentesis of the Distal Intertarsal Joint Using Radiographic Guidance

Josh R. Donnell, DVM, MS, DACVSMR†; David D. Frisbie, DVM, PhD, DACVS, DACVSMR*; and Alan D. Donnell, DVM

1. Introduction
Distal tarsal pain is a common cause of lameness in the horse. Diagnosis and treatment commonly involves diagnostic analgesia (blocking) and therapeutic injection within the tarsometatarsal (TMT) and distal intertarsal (DIT) joints.1 Historically, some controversy exists between clinicians on whether the TMT and DIT joints should be treated as two separate joints or as joints that communicate. Communication between the TMT and DIT joints has been shown to occur naturally in 8–35% of horses.2–6 Even though there have been reports of medication reaching therapeutic levels within the DIT joint following a single injection into the TMT joint, the authors’ extensive clinical experience mandates the TMT and DIT joints should be treated as separate joints.7–9

In the authors’ opinion, it is not uncommon for practitioners to only treat the TMT joint based on familiarity and ease of performing an arthrocentesis of the TMT joint coupled with the lack of familiarity and ease of arthrocentesis of the DIT joint. This statement is further supported by a recent report reporting the accuracy of blinded injection of contrast medium into the TMT and DIT joints to be 96 and 42%, respectively.5 This is likely in part due to landmarks of the DIT joint being less-well defined compared with the TMT joint. In a literature search of “equine distal intertarsal arthrocentesis” on January 16, 2016, using PubMed and Google scholar, the authors were able to define a single approach (plantar lateral) to the TMT joint and two different approaches (medial and dorsolateral) each having multiple descriptions and landmarks defined for DIT arthrocentesis.1,10–12

The medial approach to the DIT relies on ill-defined landmarks (i.e., gap between the talus and central tarsal bone), which can be difficult to palpate, in the authors’ experience, compared with landmarks (distal aspect of the lateral trochlear ridge and lateral digital extensor tendon) using the dorsolateral approach. A safe position for the clinician during the procedure is another advantage of using a dorsolateral approach over the medial approach. Accuracy, de-
fined by the deposition of therapeutic or anesthetic product into the DIT joint compartment on the first attempt, has been shown to be 42% using the medial approach.\(^5\) Reports also suggest other structures (i.e., proximal intertarsal joint, tarsocrural joint, TMT joint, and cunean bursa) can be inadvertently accessed during DIT joint injections using the medial approach.\(^1,10,12\) Accuracy using the dorsolateral approach has been shown to be 70%.\(^11\) The authors prefer the dorsolateral technique based on reported accuracy, the easily palpable landmarks and the potentially safer position for the clinician.

Although the reported accuracy is 70% using the dorsolateral approach to the DIT joint, in the authors’ practice 30% is an unacceptable failure rate. For these reasons the authors always use radiograph guidance and a dorsolateral approach to the DIT joint. This “how-to” paper describes the technique.

2. Materials and Methods
To test the accuracy of the technique described by the authors, the following study was undertaken in a prospective manner. Using a sterile field created by the paper wrapper of a set of sterile gloves, the authors use a 20-gauge 1.5-in. needle when performing both intra-articular blocking and therapeutic treatment (Fig. 1). Blocking is routinely performed with 2–4 mL mepivacaine (20 mg/mL) in a 6-or 12-mL syringe. Therapeutic treatment is typically 22 mg (2 mL) of a high-molecular-weight sodium hyaluronate (HA) and 2–4 mg (0.2–0.4 mL) of triamcinolone acetonide (TA) mixed in the same glass syringe. The arthrocentesis is performed after aseptically preparing the dorsolateral aspect of the hock alternating betadine and alcohol for a 5-minute period. In the authors’ practice it is rare to sedate the horse during the procedure. Horses are restrained with the use of a nose twitch and occasionally a technician holding up the ipsilateral forelimb. The needle is placed perpendicular to the skin, directed plantar medial, 1 cm distal to the distal aspect of the lateral trochlear ridge of the talus, which is easily identified using digital palpation. The needle is advanced until bone is contacted (Fig. 2). If the dorsal pedal vein or tarsal artery is punctured the needle is advanced or redirected slightly proximally until bleeding stops. A plantar lateraldorsomedial oblique radiograph is taken to confirm needle position relative to the DIT joint space (i.e., distal aspect of the central tarsal bone and proximal aspect of the third tarsal bone) (Fig. 3). If the needle is at the level of the DIT joint space, medication is administered, if not, the needle is redirected in the appropriate direction and the radiograph repeated (Figs. 4, 5, and 6). Correct needle placement at the level of the DIT joint space, and the number of times redirection of the needle was required (postradiographic imaging) was recorded over a 2-day period in all DIT arthrocentesis attempts.

3. Results
Arthrocentesis of the DIT joint was performed 32 times. Radiographs confirmed the needle was correctly placed on the first attempt 24 times (75%). The needle was repositioned to the correct location with one attempt in the remaining eight cases (25%). Within the last 7.5 years, in the authors’ practice, arthrocentesis of the DIT has been performed greater than 5000 times using the described technique. To date, none of the authors have been kicked or injured while performing this technique. In one instance, the digital radiograph plate was damaged from a kick. The dorsal pedal vein or

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Fig. 1. Sterile field created by the paper wrapper of a set of sterile gloves with therapeutic medication and needles.

Fig. 2. Picture of right hock with the needle placed 1 cm distal to the distal aspect of the lateral trochlear ridge of the talus.
artery is punctured approximately 30% of the time. To the authors’ knowledge there have not been any complications (i.e., hematoma, phlebitis or arteritis) associated with puncture of vein or artery.

4. Discussion
In the authors’ opinion the described technique provides better accuracy, easier palpable landmarks, ability to use clinician-preferred needle, a higher-quality standard of care, and safer approach to performing arthrocentesis of the DIT joint compared with the blinded or radiograph-guided medial approach. Although accuracy, as previously defined, has not been reported here, needle placement without radiograph guidance perpendicular to the DIT joint space (75%) was similar to reported accuracy (70%). When using radiographs to provide guidance for needle placement, the needle was at the level of the DIT joint 100% of the time in this report; with the use of two confirmation radiographs.

In the described dorsolateral technique, a site 1 cm distal to the distal aspect of the lateral trochlear

Fig. 3. Example of a plantar lateral-dorsomedial radiograph being taken by one technician to identify needle placement.

Fig. 4. Plantar lateral-dorsal medial oblique radiograph after needle placement. The needle is at the level of the DIT. Joint and mediation was injected.

Fig. 5. Plantar lateral-dorsal medial radiograph after needle placement. The needle is halfway between the DIT and TMT joint spaces. In this case the needle was redirected proximally approximately 5 mm and the radiograph was retaken.

Fig. 6. Plantar lateral-dorsal medial oblique radiograph after needle placement. The needle is between the level of the proximal and distal intertarsal spaces. In this case the needle was redirected distally approximately 5 mm and the radiograph was retaken.
ridge of the talus, which is easily palpable for clinicians of any experience level, was described as the injection site for DIT arthrocentesis. This differs slightly from a previous report, which is most likely due to the horse population being different between reports.\(^1\) The authors’ practice is almost exclusively a Quarter Horse and Arabian Western Performance horse practice. The size, conformation, and position of the hock (flexion or extension) can cause the needle to be placed in a different position relative to the DIT joint space when the described technique is used. In the authors’ experience, a more distal injection site approximately 1.5 cm to the lateral trochlear ridge is used when injecting larger horses (i.e., Warmblood breeds). Furthermore, it is important to note the position of the limb and always place the needle perpendicular to the skin and identify needle placement with a radiograph.

Radiographic guidance can be performed using any approach during arthrocentesis. When comparing the medial and dorsolateral approaches a 22-gauge 1-in. needle is most common for the medial approach.\(^2,3\) As described, the author routinely uses a 20-gauge needle to perform arthrocentesis of the DIT joint. In the authors’ opinion a 20-gauge needle facilitates the injection of the high-molecular-weight HA, which is routinely used when therapeutically treating the DIT joint. It is not without question that a 20-gauge needle could be used to administer medication into the DIT via the medial approach, but in the authors’ experience, there seems to be a very small space on the medial aspect of the hock compared with dorsolateral aspect of the hock and the entire bevel of a 20- or a 22-gauge needle does not completely enter the DIT joint compartment medially. This, in part, causes some of the medication to be administered into subcutaneous tissue when the medial approach is used.

As mentioned previously, it is the authors’ experience that the TMT joint is treated alone based on familiarity and ease of performing an arthrocentesis of the TMT joint coupled with the lack of familiarity and ease of arthrocentesis of the DIT joint. In the authors’ experience it is not uncommon to perform intra-articular blocking, with a low volume (2–4 mL) of 2% mepivacaine, into the TMT joint space only and get a significant improvement in lameness when horses have distal tarsal pain. Subsequent to this, with the thought that medication has similar diffusion rates between the TMT and DIT joints and the TMT joint is routinely an easier joint to inject, only the TMT joint is treated. The diffusion of low-molecular-weight products (i.e., methylprednisolone acetate, triamcinolone acetate, and mepivacaine) across adjacent joint space has been reported to be 100%.\(^4,5\) In the authors’ belief that diffusion of mepivacaine most likely reaches analgesic levels into the DIT joint compartment. The authors’ clinical experience has led them to believe the diffusion of HA (high molecular weight) and TA (low molecular weight) exists between the TMT and DIT joints but does not reach therapeutic levels, except when communication naturally occurs (8–35%).\(^6\) This belief has stemmed from the fact that it is not uncommon for horses to present for lameness with a history of having only the TMT joint therapeutically treated. In these cases, a large percentage of horses will significantly improve after intra-articular blocking of the DIT joint alone and become sound after therapeutically treating DIT joint alone. Subsequently, clients become frustrated with the fact that the previous treatment did not resolve the lameness and they have to pay for treatment of the same area. Clients often make the comment that the previous clinician either did not get the needle into the joint or used the wrong medication. For these reasons, the authors’ always therapeutically treat the TMT and DIT separately with HA and TA using the dorsolateral approach and radiographic guidance to the DIT joint in an effort to eliminate any doubt, in the clinician’s and owner’s mind, that the medication was administered into the desired compartment.

Disadvantages to the described technique include at least one extra person to perform radiographs, potential damage to equipment, a digital radiograph machine, and puncture of the dorsal pedal vein or tarsal artery. In the authors’ practice a single person (Fig. 3) routinely holds the radiograph machine and digital plate to take the radiograph. Two people may be needed depending on technician experience, strength, and equipment being used. To date, the authors have no knowledge of any complications from puncture of the dorsal pedal vein or tarsal artery. In the authors’ experience, when the artery or vein is punctured, further advancement of the needle through the vein or artery almost always guarantees the needle is at the level of the DIT joint space.

In conclusion, naturally occurring communication between the TMT and DIT joint has been shown to be infrequent; therefore, for practical purposes, the clinician should assume the TMT and DIT joints do not communicate when diagnosing and therapeutically treating horses with distal tarsal pain. When performing arthrocentesis of the DIT joint, no matter which approach is used, a radiograph should be taken to identify needle location. A dorsolateral approach with radiographic guidance eliminates doubt as to where the needle is positioned. Advantages to the dorsolateral approach using radiograph guidance provides easier palpable landmarks, ability to use clinician-preferred needle, a high-quality standard of care, and safer approach to performing arthrocentesis of the DIT joint compared with the blind or radiograph-guided medial approach.
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Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

References
Accuracy of a Single-Needle Injection Technique to the Three Compartments of the Equine Stifle

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The single-needle injection technique to the three joint compartments of the equine stifle is feasible and highly accurate for inexperienced and experienced injectors. Authors’ address: Orthopaedic Research Center, Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: valerie.moorman@colostate.edu *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
A single approach to all three joint compartments of the stifle has been described, but a detailed description and accuracy have not been previously reported. The objectives were to describe external landmarks and to determine the accuracy of the technique for inexperienced and experienced injectors. The authors hypothesized that this single-needle technique would have high accuracy (>80%) for successful injection of all three joint compartments.

2. Materials and Methods
The injectors consisted of three third-year veterinary students and one veterinarian. Twenty-four cadaver stifles were placed in a customized stand at an angle determined from live horses in normal square stance. Each joint compartment was injected with a solution containing contrast media, tap water, and dye. Following injection, radiographs and gross dissection were completed to determine success of entering each joint compartment. Student t tests and ANOVA were used to compare means with significance set at \( P < 0.05 \).

3. Results
The single-needle technique had >87.5% accuracy for all joint compartments. The average needle depth was 5.72 cm. The average needle angle of insertion was 81.4° (medial femorotibial [MFT] and lateral femorotibial [LFT] joints) and 16.6° (femoropatellar joint [FPJ]) relative to the tibia and 28° medial (MFJT), 7.3° lateral (LFTJ) and 1.3° lateral (FPJ).

4. Discussion
Results support the single-needle technique as an accurate method to successfully inject all three stifle compartments.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Effects of Intra-Articular Anti-Nerve Growth Factor mAb in an Equine IL-1β Synovitis Model

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Intra-articular injections of anti-nerve growth factor (equinized anti-NGF mAb NV-03; Nexvet Biopharma) significantly reduce the progression of pain, inflammation, and catabolic activity in an induced synovitis model. Authors’ addresses: Orthopaedic Research Center, Department of Clinical Sciences (King, Frisbie, Nelson), Clinical Pathology Section Department of Microbiology, Immunology, and Pathology (Olver), Colorado State University, Fort Collins, CO 80523; Nexvet Biopharma Pty, Ltd. Melbourne 3000, Australia (Gearing); e-mail: david.frisbie@colostate.edu. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Equine pain management is one of the most challenging issues veterinarians face on a daily basis. With our increased understanding of the underlying mechanisms causing various types of pain comes a need to develop more directed multimodal pain management protocols. Administration of anti-nerve growth factor (anti-NGF mAb) in nonequine species has a significant analgesic effect.

2. Materials and Methods
This nonterminal study used 24 horses and created a transient mild synovitis in one randomly selected tarsocrural joint. Each horse received a single intra-articular injection of equine recombinant interleukin-1 beta (reIL-1β), whereas an equivalent amount of sterile phosphate-buffered saline (PBS) solution was injected into the contra-lateral joint. Anti-NGF mAb was administered intra-articularly 4 hours after induction of synovitis into the reIL-1β- and PBS-treated joints. Treatment groups consisted of anti-NGF mAb dose 1 (0.1 mg), dose 2 (1 mg), dose 3 (10 mg), or placebo. Synovial fluid, lameness evaluation, and ground-reaction forces were collected at three different time points. Standing arthroscopy was used to collect tissue biopsies from the tarsocrural joint 10 hours after synovitis induction.

3. Results
The 1-mg and 10-mg doses produced significant disease-modifying effects with a reduction in synovial membrane intimal hyperplasia, synovial fluid PGE₂ and glycosaminoglycan (GAG) concentrations compared with reIL-1β placebo treatment. Significant clinical improvements with less pain demonstrated during hock flexion and a symmetrical loading of the limb were produced at the 10-mg dose.
4. Discussion
Results of this study demonstrate an effective suppression of inflammation, pain, and catabolic activity in horses in which IL-1β induced inflammatory responses were treated with intra-articular anti-NGF.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

The Colorado State University Institutional Animal Care and Use Committee approved the study protocol for this experiment: protocol No. 15-5567A.

Conflict of Interest
This work was funded by Nexvet Biopharma. Dr. Gearing is an employee of Nexvet Biopharma Pty, Ltd.
Review of Bisphosphonate Use in Horses

Katja F. Duesterdieck-Zellmer, Dr.med.vet., MS, PhD, DACVS

Some horses with navicular syndrome improve 2–6 months after bisphosphonate administration and repeated treatment may benefit previously unsuccessfully treated horses. Systemically administered bisphosphonates may cause colic or renal failure and NSAIDs or other nephrotoxic drugs should not be administered concurrently. Regional limb perfusion or intraarticular administration may not be as efficacious as systemic administration and may risk cartilage damage.

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1. Introduction

The bisphosphonates tiludronate and clodronate were approved by the U.S. Food and Drug Administration (FDA) in 2014 for “the control of clinical signs associated with navicular syndrome in horses.” Both are non-nitrogen-containing bisphosphonates that have been used in humans for the treatment of osteoporosis as they influence bone remodeling toward an increase in bone mass and mechanical strength. The use of bisphosphonates among equine practitioners seems to be controversial with many having strong opinions for or against the use of these drugs in equines. Questions remain regarding the best choice of bisphosphonate, frequency, route and dose of administration, minimum age of the horse to be treated, what type of conditions may benefit from treatment, and how to select the best candidates for successful bisphosphonate treatment. This paper provides a review of the pharmacokinetics, mechanisms of action, adverse effects, and specifics about different routes of administration of bisphosphonates in horses and other species to allow the equine practitioner to make educated choices when considering treating a patient with bisphosphonates.

2. Pharmakokinetics

After IV or IM administration, non-nitrogenous bisphosphonates localize primarily in bone, but small amounts can also be found in the kidneys, liver, and spleen. The majority of the systemic dose is, however, excreted via the kidneys, which likely explains potential nephrotoxicity of bisphosphonates. In the bone, bisphosphonates bind with a very high affinity to hydroxyapatite crystals (bone mineral). They seem to be absorbed especially well at sites of active bone resorption, where bone mineral is most exposed. Here, bisphosphonates remain until being liberated via slowed bony resorption. Thus, the half-life of bisphosphonates in bone depends on the affinity to calcium of the specific bisphosphonate and on the rate of bone turnover, but has been described for alendronate to be 3 years for dogs, more than 10 years for humans, and 300 days was reported as bone half-life for pamidronate in rats. Unfortunately, no data are available for horses, but the author’s opinion is that half-life within bone is likely to be variable depending on location within the skeleton and presence or absence of pathologically increased bone turnover. Thus, regions with normal
turnover may still contain bisphosphonates at the same time as regions with abnormally high turnover have cleared bisphosphonates.

3. Mechanisms of Action
In the opinion of the author, it is imperative to familiarize oneself with the unique mechanisms of action of bisphosphonates, given that they can explain adverse effects and knowledge of the mechanisms of action allows veterinarians to make better clinical decisions where data in horses is lacking. The mechanisms of action of non-nitrogenous bisphosphonates have been investigated extensively. They inhibit bone resorption mostly via a cellular mechanism on osteoclasts. Osteoclasts take up bisphosphonates during acidic dissolution of mineralized bone matrix. Intracellularly, the non-nitrogenous bisphosphonates are then incorporated into toxic ATP analogs that are resistant to hydrolysis. This disrupts energy-dependent cellular functions of the osteoclasts, resulting in osteoclast apoptosis and inhibition of bone resorption. Interestingly, tumor necrosis factor-α (TNFα) can rescue osteoclasts from non-nitrogenous bisphosphonate-induced apoptosis, possibly explaining why these bisphosphonates have not been as effective in some inflammatory models of bone loss with high levels of TNFα. Besides these direct effects on osteoclasts, bisphosphonates also interfere with osteoclast formation and maturation. This results in decreased heterogeneity of bone mineral and matrix properties and accumulation of local microdamage, which translates into deterioration of mechanical properties of the bone, especially at sites of maximum mechanical forces. Although there are no reports of atypical fractures in horses after bisphosphonate use, it is important for veterinarians to realize that similar complications could occur in horses especially after repeated bisphosphonate use. Renal toxicity is a well-known adverse effect of bisphosphonate use in humans, and the author knows of multiple equine cases in which there is an anecdotal link to bisphosphonate administration. Both tiludronate and clodronate are labeled with statements not to use them in horses with a history of or current renal disease. Both also have statements to avoid concurrent administration of NSAIDs (tiludronate) or to approach the “concurrent administration of other potentially nephrotoxic drugs... with caution and renal function should be monitored” (clodronate). In tiludronate’s FDA approval study, horses that were treated with flunixin after tiludronate injection showed significantly higher serum creatinine, blood urea nitrogen (BUN), and calcium and magnesium levels compared with pre-treatment values, and 32% of horses had serum creatinine levels above the reference range but returned to the reference range 2 weeks post-treatment. In horses that were treated only with tiludronate, 2% had elevated serum creatinine levels. After treatment with clodronate (1.4 mg/kg IM), serum creatinine, BUN and potassium levels

4. Adverse Effects
Adverse effects or undesired effects of bisphosphonate use have been and are still debated in length in the human medical field, but have not received the same attention among the veterinary medical community, at least not in the peer-reviewed literature. In humans, osteonecrosis of the jaw has been a puzzling, severe adverse effect of bisphosphonate use, especially when administered intravenously to patients with cancer. However, patients receiving bisphosphonates for treatment of osteoporosis may also experience this complication, especially if other risk factors, such as corticosteroid use, alcohol consumption, immunosuppressive therapy, autoimmune diseases, hematologic/thrombotic disorders, diabetes mellitus, or renal failure are present. To the author’s knowledge, osteonecrosis of the jaw has so far not been reported in horses, but it is important to be aware of its association with bisphosphonate use in humans. Another severe complication of bisphosphonate use in humans is the occurrence of atypical femoral fractures. These are thought to be fatigue or stress fractures, and it has been proposed that continued bisphosphonate administration results in alteration of the normal remodeling response, consisting of osteoclastic bony resorption followed by osteoblastic bone formation. This results in decreased heterogeneity of bone mineral and matrix properties and accumulation of local microdamage, which translates into deterioration of mechanical properties of the bone, especially at sites of maximum mechanical forces. Although there are no reports of atypical fractures in horses after bisphosphonate use, it is important for veterinarians to realize that similar complications could occur in horses especially after repeated bisphosphonate use. Renal toxicity is a well-known adverse effect of bisphosphonate use in humans, and the author knows of multiple equine cases in which there is an anecdotal link to bisphosphonate administration. Both tiludronate and clodronate are labeled with statements not to use them in horses with a history of or current renal disease. Both also have statements to avoid concurrent administration of NSAIDs (tiludronate) or to approach the “concurrent administration of other potentially nephrotoxic drugs... with caution and renal function should be monitored” (clodronate). In tiludronate’s FDA approval study, horses that were treated with flunixin after tiludronate injection showed significantly higher serum creatinine, blood urea nitrogen (BUN), and calcium and magnesium levels compared with pre-treatment values, and 32% of horses had serum creatinine levels above the reference range but returned to the reference range 2 weeks post-treatment. In horses that were treated only with tiludronate, 2% had elevated serum creatinine levels. After treatment with clodronate (1.4 mg/kg IM), serum creatinine, BUN and potassium levels
were not significantly increased compared with pretreatment values in any of the study horses.\textsuperscript{21} When clodronate (1.8 mg/kg IM) was administered after 3 days of phenylbutazone treatment at 4.4 mg/kg twice daily and followed by 3 days of phenylbutazone at 2.2 mg/kg twice daily, serum creatinine concentrations remained within the reference range, but BUN concentration increased compared with pretreatment values. Renal toxicity due to bisphosphonates is likely associated with renal excretion of the bisphosphate. With high local bisphosphonate concentrations in the kidneys, cells likely will take up the drug and go into apoptosis. Thus, in the author’s opinion, administration of lower doses or over a longer period may help to decrease renal toxicity.

Gastrointestinal pain is also a common adverse effect of systemic administration of bisphosphonates in horses. Although there is little mention of this in the peer-reviewed literature, colic associated with IV infusion of tiludronate was seen in 58% of horses treated with tiludronate at 1 mg/kg in 1 L saline, administered over 30 minutes, in 28% of horses when the administration time was extended to 60 minutes and in 44% of horses when the administration time was extended to 90 or 120 minutes.\textsuperscript{20,21} Fewer than half of the horses experiencing colic required medical therapy, and duration of colic signs was 7 minutes to 6½ hours (mean, 81 min). In horses treated medically for signs of colic, these signs resolved within 15 minutes after initiation of colic treatment (including N-butylscopolamine, xylazine, detomidine, butorphanol, and flunixin, although the latter is not recommended). After IM injection of clodronate at 1.4 mg/kg with a maximum dose of 900 mg, 9% of horses exhibited colic signs immediately post-treatment. However, horses exhibiting just a single sign of colic, such as pawing, pacing, agitation or depression were not counted as showing signs of colic. Only 0.9% of all horses required medical treatment (flunixin and dexamethasone, which is in the author’s opinion not to be recommended) to resolve colic signs as well as heaves associated with clodronate treatment.\textsuperscript{21} Colic signs occurred from 1 to 226 minutes postinjection and all had resolved within 5½ hours post injection. In the author’s opinion, a horse exhibiting signs of colic after bisphosphonate treatment should first be walked and if this does not resolve signs, N-butylscopolamine, xylazine, detomidine, butorphanol, or a combination of these drugs should be given.

Other, less-frequent adverse effects in these studies\textsuperscript{20,21} were injection site swelling, frequent urination, muscle fasciculations, inappetence, anorexia, stiff neck, and fever for tiludronate and lip licking, yawning, head shaking, injection site swelling, hives, and pruritus for clodronate.

One horse that was confirmed to be a heterozygous carrier of the hyperkalemic periodic paralysis (HYPP) gene died after becoming colicky post-tiludronate infusion and receiving a dose of an unknown NSAID and xylazine. This horse had severe hyperkalemia, moderate hypercalcemia, mild azotemia, and signs of hemococoncentration. The presumptive cause of death after necropsy was cardiovascular arrest due to hyperkalemia.\textsuperscript{20} In the author’s opinion, it is important to discuss a possible increased risk for an HYPP episode with owners of carriers, and electrolyte status of horses with muscle fasciculations or signs of colic that do not resolve with walking should be determined to allow for appropriate treatment.

5. Clinical Use in Horses

Use of IV-Administered Tiludronate for Treatment of Navicular Syndrome

There is evidence that IV-administered tiludronate is beneficial for some cases with navicular syndrome.\textsuperscript{22,23} Based on a double-blind placebo-controlled trial, 22 horses with moderate-to-severe lameness (2–5 of 5 grade lame on American Association of Equine Practitioners [AAEP] scale), positive interphalangeal extension test, positive palmar digital nerve block, and classic radiographic signs of navicular disease may benefit from treatment with tiludronate (0.1 mg/kg four times daily for 10 consecutive days, resulting in a total dose of 1 mg/kg tiludronate), especially if their clinical signs occurred less than 6 months prior to initiation of treatment. Horses with signs of lameness of more than 6 months duration seemed to need two or three treatments 2 months apart. Improvement in lameness was reported in almost 70% of horses, and resolution of lameness was reported in 50% of horses 6½ months after treatment. The decision to repeat treatment was made based on lack of improvement 2 months after the initial treatment. Another study reported that horses’ lameness due to navicular syndrome improved 120 and 200 days after tiludronate treatment (1 mg/kg IV), but none of the horses became sound.\textsuperscript{23} All horses received trimming “for balance” by an experienced farrier throughout the study period. In the author’s opinion, these studies show that it may take a long time for tiludronate to provide pain relief in horses with navicular syndrome, and the inclusion of appropriate shoeing may be necessary to improve outcomes. They also show that response to treatment can be quite variable. The FDA approval study, although not peer reviewed, also supports the effectiveness of intravenously administered tiludronate (1 mg/kg) to decrease lameness due to navicular syndrome in some horses.\textsuperscript{20} To be included in this study, horses had to be at least 4 years of age, the cause of lameness had to be navicular syndrome based on lameness examination including response to palmar digital nerve block, bone edema of the medullary cavity of the navicular bone, and no major soft tissue involvement on magnetic resonance imaging examination. Further, horses had to be a grade 2–3
lame on the AAEP lameness scale and had to be free of renal disease. Most horses were lame for fewer than 6 months at the time of treatment and all horses received “corrective shoeing” as part of the treatment. At 2 months post-treatment, 64% of treated horses had improved at least by 1 lameness grade on their predominantly lame limb and had not worsened in the other limb (vs 48% of placebo horses).

Use of IM-Administered Clodronate for Treatment of Navicular Syndrome

There is no peer-reviewed information available on the effects of clodronate administration on horses with navicular syndrome. The FDA approval study21 supports effectiveness in decreasing lameness due to navicular syndrome after IM injection of clodronate (1.4 mg/kg with a maximum dose of 900 mg) in some horses without making shoeing changes in these horses. To be included in this study, horses had to be at least 4 years of age, the cause of lameness had to be navicular syndrome based on lameness examination including response to palmar digital nerve block, bony changes that were characteristic for navicular disease on radiographs, absence of other lesions on radiographs, and no shoeing changes within 2 weeks prior to treatment. At 56 days post-treatment, 75% of treated horses had improved at least by 1 lameness grade on their predominantly lame limb and had not worsened in the other limb (vs 3% of placebo horses). At 180 days after treatment, 85% of the horses considered a success at 56 days were still improved by at least 1 lameness grade on their predominantly lame limb and had not worsened in the other limb. However, 41% of these were more lame than at the 56-day time point, indicating that the treatment effect may have decreased between 2 and 6 months post-treatment. The overall success rate at 180 days was 65% of treated horses.

Conclusion From Studies for Tiludronate and Clodronate

In the author’s opinion, there is currently no evidence that either tiludronate or clodronate is more efficacious than the other in relieving pain due to navicular syndrome in horses, although the two studies had significant differences in study design (magnetic resonance imaging, incorporation of shoeing changes, definition of colic).

6. Extra-Label Bisphosphonate Use

Extra-Label Routes of Administration of Tiludronate

The relatively high cost of the drug, adverse effects encountered at the dose of 1 mg/kg IV, and anecdotal reports of greater efficacy for more targeted routes of administration have presumably resulted in veterinarians administering tiludronate via intraarticular (IA) injections or via IV regional limb perfusion (RLP). This is despite very little information about appropriate dosing regimens, safety, or efficacy of these practices. When attempting to predict possible effects of administration of tiludronate via IA injections or RLP, it is important to understand the concentration-dependent effects of bisphosphonates on cells in bone and cartilage, as well as other musculoskeletal tissues, given that the more targeted routes of administration will invariably result in some kind of effect on joint tissues other than bone, due to relatively high synovial fluid concentrations attained via IA injection or RLP. In vitro experiments on articular cartilage explants24 showed that concentrations of tiludronate that could be expected after administration of 50 mg of tiludronate into a joint with a volume of 30 mL (tibiotarsal or femorotibial joints) increased release of glycosaminoglycans (GAG) from cartilage matrix as well as chondrocyte apoptosis in normal and IL-1 challenged cartilage. In contrast, low-to-moderate tiludronate concentrations (≤ 1900 ng/mL) decreased GAG release and chondrocyte apoptosis. These results raise concern about the current practice of IA injections or RLP with high doses of tiludronate. However, they also suggest that at the right dose, tiludronate may be beneficial in the treatment of osteoarthritis or navicular disease when given via more targeted routes.

In another study,25 four horses’ middle carpal joints were injected with a dose of tiludronate designed to reach safe and efficacious levels in the synovial fluid (dose of 0.17 mg tiludronate IA). Four different horses’ middle carpal joints were injected with 50 mg tiludronate to reflect the accidentally used dose and this dose generated synovial fluid tiludronate concentrations exceeding those considered safe for articular cartilage in vitro (≤ 1900 ng/mL) for at least 48 hours after IA injection. This was accompanied by increased synovial fluid total solids concentration, suggesting an inflammatory response, as well as an increase in synovial fluid GAG concentration, resulting from increased cartilage matrix degradation. Nevertheless, 14 days after treatment, GAG content in articular cartilage was not found to be different between joints treated with the high dose of tiludronate and control joints, although this may reflect the small number of horses investigated. Although it seems that IA injection of 50 mg tiludronate into middle carpal joints of healthy horses results in a transient inflammatory response and GAG release from articular cartilage, it is uncertain whether this practice has any long-term negative effects on joint health. In the author’s opinion, the repeated IA use of higher doses of tiludronate may have more detrimental effects than what was reported in this study.

In another study, 26 IV RLP was performed on one forelimb of six horses with a dose of tiludronate (0.5 mg diluted with saline to 50 mL) designed to reach safe levels in the synovial fluid. Six other horses had RLP of one forelimb with 50 mg tiludronate (diluted with saline to 50 mL). All contralateral forelimbs received RLP with 50 mL saline to serve
as control limbs. Similar to other studies investigating synovial fluid disposition of medications administered via IV RLP, synovial fluid concentrations of tiludronate were quite variable. With the high dose of tiludronate, synovial fluid tiludronate concentration exceeded concentrations considered to be safe for articular cartilage in vitro (≤ 1900 ng/mL) in two of the six coffin joints. There was no difference between treated and control limbs in synovial fluid total solids concentration at any time in any synovial structure, and GAGs were not measured in this study due to the small volumes of synovial fluid samples obtained.

Interestingly, RLP with tiludronate (0.1 mg/kg) in horses with navicular syndrome failed to improve lameness over a time period of 200 days, whereas systemic administration (1 mg/kg tiludronate IV) improved lameness in a similar population of horses.23 In the author’s opinion, higher doses for RLP may provide better clinical response, but the safety of higher doses for cartilage and other tissues within the perfused area needs to be established before higher doses are being used by veterinarians.

In conclusion, IA injections and RLP with tiludronate will have dose-dependent effects on bone and cartilage and optimal dosing regimens need to be developed based on scientific principles. Until that goal is achieved, these routes of administration cannot be recommended.

7. Bisphosphonate Administration to Manage Osteoarthritis

The usefulness of bisphosphonate treatment to manage lameness due to osteoarthritis is not necessarily intuitive, given that bisphosphonates influence bone remodeling toward an increase in bone mass and mechanical strength,1 and other than in certain types of osteoarthritis (such as bone spavin, for example), osteoarthritis in horses is typically associated with subchondral bone sclerosis, rather than lysis. Thus, the question may arise why one would use a class of drugs that decreases bone resorption in conditions that are radiographically characterized by already too much bone? The short answer to this is that other than in late-stage osteoarthritis, remodeling (which is the coordinated removal of bone by osteoclasts, followed by the formation of secondary bone by osteoblasts in the same location) of the subchondral bone is accelerated with osteoarthritis.27,28 There is also evidence pointing toward this acceleration in bone remodeling being a major culprit in the progression of osteoarthritis.29 Thus, bisphosphonates have the potential to slow progression of osteoarthritis by normalizing the accelerated bone remodeling in the subchondral bone area of osteoarthritisic joints. It is likely that bisphosphonates are more effective when administered early in the disease process, given that bone remodeling actually is slowed down in late-stage osteoarthritis.37,28 In the author’s opinion, this is probably one major reason for inconsistent results of studies investigating the effects of bisphosphonate therapy on osteoarthritis in experimental animal studies and human clinical trials.

Tiludronate has been shown in double-blind, placebo-controlled clinical trials to improve pain due to osteoarthritis of the thoracolumbar facet joints30 and bone spavin31 in some horses.

Briefly, horses with reduction in thoracolumbar movement during passive mobility or while trotting or cantering, no or minimal lameness, and radiographic signs of osteoarthritis if the facet joints in the thoracolumbar region with or without radiographic lesions of the dorsal spinous processes may show an increase in dorsal mobility especially at a canter with tiludronate treatment (1 mg/kg IV). In the study, more than 60% of treated horses were considered to have responded positively 60 days after treatment, whereas almost 30% of placebo treated horses were considered to have responded positively. It is important to note that the variables used to determine positive response were subjective assessments. Similarly to the navicular study,22 horses that failed to respond 60 days after the first tiludronate treatment were administered a second treatment and two of three horses did improve 60 days after the second treatment.

Tiludronate administered systemically (1 mg/kg IV) has also been shown to improve lameness due to bone spavin in some horses to a greater degree than a placebo did.31 Included horses had been lame for 2–12 months, and had had limited treatments for their condition. Lameness improved over 2–4 months post-treatment, and horses with a less-severe lameness prior to treatment seemed to be the ones that attained soundness at the end of the study.

Although veterinarians anecdotally use bisphosphonates to manage osteoarthritis of many other joints in horses, it is important to educate horse owners about the fact that this is an extra-label use of the medications and that there is no peer-reviewed evidence available for their effectiveness in conditions other than the ones discussed above. This does not mean that they cannot be effective, but at this time, there is insufficient evidence to make such a statement.

8. Bisphosphonates to Prevent Disuse Osteopenia

Tiludronate administered at 1 mg/kg diluted in 1 L saline given IV over 30–60 minutes was able to prevent a decrease in bone mineral density due to cast immobilization in horses.32 Lameness observed immediately after cast removal (grade 3–4/5, AAEP lameness scale) was not influenced by tiludronate administration. Thus, the author’s opinion, bisphosphonate administration may be a reasonable adjunctive treatment in cases that need prolonged cast immobilization to prevent loss in bone mineral density, which is thought to decrease bone strength.

If the cast is applied to aid in fracture healing or after surgical arthrodesis of a joint, the question arises whether previous or current bisphosphonate
use may be detrimental to formation of a bony union, because osteoclast activity is an integral part of fracture repair. To the author’s knowledge, there are no studies on the effects of bisphosphonates in horses with experimentally induced fractures. Furthermore, results from human reports are difficult to extrapolate to equines, because most humans treated with bisphosphonates have bone diseases that may affect fracture healing in the first place, such as osteoporosis. In the author’s opinion, only studies on animals with normal bone homeostasis should be used to attempt to gather information about whether bisphosphonate use is detrimental in equine fracture patients. Based on one review article and two meta-analyses, one may conclude that bisphosphonate administration shortly before or after fracture occurrence is unlikely to affect indirect or secondary fracture healing negatively; while bisphosphonates seem to result in a larger callus and delayed remodeling of woven bone to lamellar bone within the callus, biomechanical properties of the callus do not seem to be inferior. In contrast with this, bisphosphonate use in direct or primary bone healing resulted in biomechanically inferior healing of osteotomy sites. In the author’s opinion, the use of bisphosphonates in horses with fractures or surgical arthrodesis needs to be investigated before clinical application can be advised.

A decrease in bone mineral density may also occur during lay-up periods in athletic horses, and such periods have been associated with an increased risk of certain catastrophic fractures once training and racing is resumed. It is unknown whether administration of a bisphosphonate would decrease or increase the incidence of catastrophic fractures after lay-up periods.

9. Bisphosphonates for the Treatment of the Bucked Shins Complex

A non-peer-reviewed report described the use of tiludronate (via IV RLP), extracorporeal shockwave therapy, and exercise modification in horses with sensitivity to palpation of the dorsal aspect of the third metacarpal bone and radiographic evidence of a stress fracture or periosteal remodeling and bone loss in that area. Five horses were treated with 50 mg tiludronate via IV RLP (total volume of 60 mL, perfused for 30 min) every 2 weeks for three treatments, extracorporeal shock wave application (5-mm trode, 1000 pulses at energy level 60% every week for six treatments and exercise restriction to 10 minutes of hand-walking daily for the first week, which was gradually increased to jogging on the track for 1.5 miles by the sixth week. All horses raced after this regimen within a range of 2.5–5 months after diagnosis without recurrence of the problem. The report also showed radiographic resolution or improvement of changes in the dorsal metacarpus at the 6-week mark in two cases. Although this report is intriguing, there was no control group, and it was not peer reviewed. Thus, it is to date unknown whether the use of tiludronate was beneficial, given that multiple treatment modalities were employed. It is also unknown whether tiludronate in these cases was safe in the long run. In other species, it has been shown that bisphosphonate use in fracture patients or experimentally induced fractures results in an increase in callus size, given that the initial anabolic bone response is not resorption dependent, and the later, resorption-dependent remodeling response is reduced. Recommendations for human patients who are being treated with bisphosphonates and that incur a fracture are to continue bisphosphonate treatment for the original condition (such as osteoporosis) unless primary bone repair is the anticipated method of fracture healing. In fact, bisphosphonate treatment after fracture creation has resulted in significant increases in mineralized callus size and strength in some studies of experimental fracture models compared with saline controls.

10. Other Musculoskeletal Conditions That May Possibly Benefit From Bisphosphonate Administration

In the authors’ opinion, nonseptic pedal osteitis and sesamoiditis may be conditions that possibly benefit from a decrease in bone remodeling, but no information is available on the use of bisphosphonates in these conditions.

11. Remaining Open Questions

How May Clodronate or Tiludronate Administration Affect Skeletal Development in Growing Horses?

All clodronate-specific studies were performed in skeletally mature horses, so one must turn to studies in other species. There are currently no guidelines for use of bisphosphonates in human pediatric patients and their use in children is controversial because of lack of safety data, but nevertheless, they are used to treat genetic or acquired disorders that are associated with osteoporosis and fracture development in children.

One complication is the development of a radiodense transverse line in the area of the metaphyses, adjacent to an active physis, corresponding with each individual bisphosphonate treatment in children with osteogenesis imperfecta. The clinical significance of this radiographic finding is however unknown, given that these lines disappear with time (range, 2–8 y). It is unknown whether similar radiographic findings occur in foals treated with bisphosphonates.

It seems that bisphosphonate exposure of the human fetus due to therapeutic doses for the mothers result in only marginal decreases in gestational length and birth weight, although transient neonatal electrolyte abnormalities seem to be more clinically significant. To date, no long-term health consequences of human fetal exposure to bisphos-
Phosphonates have been reported, but none of the studies performed long-term follow-up on the infants.

In growing laboratory animals, bisphosphonate administration was associated with a transient disruption of physeal microscopic morphology, retention of cartilaginous remnants in the cortical bone, and a mild decrease in tibial length. Thus, bisphosphonates seem to affect endochondral ossification, but it is unclear whether this has any lasting effects.

How Long Are Tiludronate or Clodronate Decreasing Bone Turnover After Administration? Is This Dependent on Exercise, Age of the Animal, or Other Factors? Is it Important to Obtain a Sustained Decrease in Bone Turnover for Therapeutic Effectiveness?

The answers to these questions remain open. The bone resorption marker CTX-1 (a peptide that is cleaved off type I collagen by osteoclasts during bone resorption) was measured up to 60 days after treatment of horses with either a single dose of tiludronate at 1 mg/kg IV or with 10 daily doses of tiludronate at 0.1 mg/kg IV. Significant decreases were seen only transiently within the first 3 days after treatment was started in either group. This study was performed in sound horses that were not exercised, and CTX-1 response in horses in training with musculoskeletal diseases that affect bone turnover may be different. One could conclude from this study that sustained suppression of CTX-1 may not be necessary to obtain a treatment effect after IV tiludronate administration, but to prove or disprove this statement, measurements of CTX-1 in horses with navicular disease before and after treatment with bisphosphonates would need to be performed.

Where Does the Dosing Regimen to Treat Every 2 Months Come From?

The author is not certain how this dosing regimen was derived, but an abstract presented at the Ninth International Congress of the European Association for Veterinary Pharmacology and Toxicology suggested that radioactivity from radioactively labeled tiludronate in equine bones decreased relatively little for the first 3 months after administration at 1 mg/kg IV, and then decreased more rapidly 3–6 months after administration. Based on extrapolation from data in rats it was concluded that tiludronate concentrations in equine bone at 6 months were probably not high enough to inhibit bone resorption by 50%.

12. Summary

A subset of horses with lameness due to navicular syndrome seems to improve after IV administration of tiludronate or IM administration of clodronate, but resolution of lameness may not be achieved.

Assessment of response should be performed 2–6 months post-treatment and in horses with failure to improve, an additional treatment may result in improved lameness. Horses with a lameness history of less than 6 months are more likely to respond to treatment.

Bisphosphonates can be nephrotoxic and a renal panel should be obtained prior to treatment. Horses with compromised kidney function are poor candidates for bisphosphonate treatment due to likely worsening of the condition.

Bisphosphonates should not be administered concurrently with NSAIDs or other nephrotoxic drugs. Colic is the most common adverse effect of bisphosphonate administration, but most horses improve with walking only. If medical treatment is warranted, N-butylscopolamine, xylazine, detomidine or butorphanol, or a mixture of these can be used. NSAID administration is not recommended.

Bisphosphonate administration may be associated with HYPP episodes in heterozygotes, although the FDA did not come to the same conclusion. No information is available for safety of bisphosphonate treatment in homozygous carriers. The author recommends analyzing the electrolyte status of horses with muscle fasciculations and/or colic signs that do not resolve with walking exercise.

According to the FDA approval studies, tiludronate administration (1 mg/kg in 1 L saline IV over 60–90 min) may be accompanied more often with colic signs or alterations of clinical pathologic variables of kidney function and electrolyte homeostasis than clodronate administration (1.4 mg/kg up to 900 mg total distributed into three different injection sites), but these studies were not peer reviewed and their description is incomplete in the FDA Freedom of Information Summaries.

Administration of bisphosphonates via routes other than what is approved by the FDA may not be innocuous or clinically effective and is not currently recommended.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References and Footnotes


44. Veratro, PulseVet, Alpharetta, GA 30009.
Radiation Exposure to Personnel Obtaining Equine Appendicular Radiographs Using a Hand-Held Generator

Katherine L. Ellis, DVM*; Alison J. Morton, DVM, MSpVM, DACVS, DACVSMR; Matthew D. Winter, DVM, DACVR; and Jorge A. Hernandez, DVM, PhD, MPVM

Scatter radiation exposure is significantly higher without lead shielding, and for personnel holding cassettes. A handheld generator may be used safely with proper shielding. Authors' addresses: Department of Large Animal Clinical Sciences, (Ellis, Morton, Hernandez); Department of Small Animal Clinical Sciences, (Winter) University of Florida College of Veterinary Medicine, Gainesville, FL 32608; e-mail: klottellis@gmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Radiation exposure in equine radiography has been minimally evaluated. A study evaluating operator exposure confirmed the benefits of shielding, but the radiographic exposure techniques used were higher than typical, and exposure to personnel holding cassettes was not evaluated. The hypotheses of this study were radiation exposure from a handheld generator would be lower with than without shielding, and exposure would be higher to the cassette holder than to the generator operator. The objectives of this study were to compare scatter radiation exposures to personnel using a handheld generator with and without shielding.

2. Materials and Methods
A cadaveric hindlimb was suspended to mimic standing position. Two dosimeters were placed at six locations from the generator and cassette to mimic locations of hands, trunk, and eyes-thyroid of personnel. One dosimeter was unshielded and the other was shielded at each location. Twenty exposures were made of each projection. Shielding techniques were compared using the Wilcoxon sign-rank test.

3. Results
Exposures for the operator and holder without shielding were significantly higher than with shielding. Relative exposure for the holder was significantly greater than for the operator. A large number of radiographic studies are necessary to reach the annual maximum exposure.

4. Discussion
Radiation exposure is significantly higher without than with shielding. A handheld generator may be
used safely as long as proper shielding techniques are employed.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Break-Even Analysis: When to Add New Equipment and Services

Mary Beth Whitcomb, DVM, MBA, ECVDI (LA-Associate)*; and Andrew R. Clark, DVM, MBA*

1. Introduction
Veterinarians can be quick to purchase the latest equipment without considering important business aspects of such purchases. Equipment purchases can be emotionally driven or driven by a real or perceived need to keep up with competitors. End-of-the-tax-year specials at trade shows can also contribute to emotional decision making. Poorly thought out purchase decisions can lead to underutilization and inadequate cost capture of new equipment or development of new services.

This lecture will cover important aspects of decision making when considering adding new equipment or services. Regardless of the type of service or equipment being added, the decision-making process is similar. One must consider pricing, opportunity cost, and training among other factors when deciding whether to purchase new or replacement equipment. Important concepts of capacity, white space, branding, and break-even analysis will be presented as they relate to such decisions. Attendees should gain a better appreciation of the decision-making process when faced with decisions to add or replace equipment or services.

2. Should I Add New Equipment/Service?
The concept of opportunity cost is one of the first concepts taught in business schools. Opportunity cost considers what you could be doing (earning) if you were doing something else with your time or money. Although it may sound straightforward, opportunity cost is often overlooked. For example, you are considering the purchase of a new ultrasound machine. You own an old portable unit that is acceptable for reproductive use, but little else. You plan to keep that machine for reproduction and purchase a new machine for musculoskeletal (MSK) exams. Multiple opportunity costs must be considered:

Opportunity Cost of Your Time
What could you do if you were not performing an MSK ultrasound exam? Do you have time to add MSK ultrasound exams into your work day? Or will adding this service affect your ability to do something else from a time standpoint? This relates to capacity in your practice. If the answer is yes to the latter, then you will have to give something up during your practice day to perform that ultrasound exam. Perhaps this means one less
lameness exam, one less dental, three less radiographic studies, seeing the next scheduled patient on time, etc. The next step is to consider what you would charge for performing those alternative tasks that you would be giving up. If you can earn more performing those tasks, and there is more demand for these tasks than MSK ultrasound, then perhaps purchasing a new ultrasound machine is not the best choice from a profitability standpoint.

Opportunity costs also relate to pricing of the ultrasound exam. Let’s say, for example, in order to spend an hour from start to finish to perform a MSK ultrasound exam (time to set up, scan, communicate findings to clients, cleanup), you would have to give up an hour doing three radiographic studies where you could gross $450 (assumption=$150/study). From a business standpoint, this is the price you should charge for your ultrasound exam. However, this price would probably be beyond most clients’ willingness to pay for an ultrasound exam, at least in most areas of the country. Admittedly, this is a fairly simplistic approach and you should consider your hourly gross in this thought process as well. Given that ultrasound exams tend to take longer than other types of exams, it is likely that your hourly gross could decline if you add MSK ultrasound to your practice. It is however also recognized that your clients may expect that your practice can perform such exams, especially if your practice demographic has changed from a rural to suburban practice. In such cases, the decision becomes somewhat more complex, even if adding MSK ultrasound means less time to perform other quicker, more lucrative, veterinary services.

Opportunity Cost of Capital

Opportunity cost of capital relates to what could be purchased with that same capital. In other words, would you have a higher return on investment if you spent that money on something else? This is a tougher question to answer, but it is one that should at least be considered. Cost of training (technician and DVM) and ongoing continuing education should also be considered in the opportunity cost of capital. All are capital investments.

Continuing education and training is expensive, and there should be a return on your investment. Will you need a new transducer for new regions? Do you have clients requesting those exams? Could your skills be better developed in other areas of your practice? Ultrasound is highly operator dependent and consumes considerable time to become competent. Clients may expect you to image any MSK region, and ultrasound is much more operator dependent than radiography. To enhance your return on investment, continuing education (CE) courses should be sought out to improve skill levels in areas of greatest capacity. Even more important to your return on investment is to ensure opportunities to practice once you return from the CE course.

Other factors to consider relate to demand and ability/competence. This is the time to be honest with yourself when considering how many times a week, month, or year do you recommend an ultrasound exam of a particular region and how often does a client seem amenable and willing to pay for it. Veterinarians sometimes want to add ultrasound into a practice that cannot support the service. It is therefore important to consider these aspects of your target market.

Let’s assume that you have clients who desire, value, and are willing to pay for such a service. You should also consider who should be performing ultrasound exams within your practice or in your practice area. Do you have the time, energy, interest, and talent to develop competence? Should it be you that ventures into ultrasound or should every one in your practice attempt to become competent? Who has the most potential and interest level? Perhaps there is one individual in the area that only performs ultrasound. In such cases, it might be more efficient and more profitable to refer to that individual. Does everyone in your practice area already perform their own ultrasound exams? And do your clients seek them out because you have not offered this service before? These questions relate to branding and the concept of white space.

3. Break-Even Analysis—Basic Version

Break-even analysis is commonly performed in other industries when making purchase decisions. There are many types of break-even analysis; some complex and some much more basic. All involve assumptions. Although there is no one right way to perform break-even analysis, some attempt should be made when considering an equipment purchase, either as a replacement or when adding a new service. We will present a basic and advanced version.

The basic version involves only a few assumptions: the price of service you will be offering and the variable costs associated with performing one service (exam). Variable costs include those costs that would only be incurred because you are performing one more exam. For example, if you perform one MSK ultrasound exam, the variable costs would include gel or alcohol used on that horse for that exam, prep material, thermal paper if you print images, per patient cost for cloud storage and the hourly rate of a technician. The veterinarian’s salary would not be considered given that this is a fixed cost (assuming they are paid full salary). From these numbers, the contribution margin can be calculated (price less variable costs). Contribution margin is essentially the amount of total revenue that can be applied toward a practice’s fixed costs. The purchase price of equipment is then divided by the contribution margin to determine the number of exams necessary before breaking even on the purchase (Fig. 1). Given the purchase price and variable cost assumptions shown in Fig. 1, break-even on the purchase of a new transducer ($7500) would
be 125 exams at a price of $100 per exam. At this point, it is important to consider demand, ability, and willingness to pay from current and prospective clients in the practice area.

Lack of consideration of variable costs is a common mistake when determining a break-even point. Fig. 2 shows the same calculation as Fig. 1, but assumes no variable costs are incurred while performing the ultrasound exam. In this case, one would errantly assume that it would only require 75 exams to break even on the purchase of the transducer. Although variable costs can be challenging to calculate, they are an important consideration. A rough estimate is better than none at all.

Let’s assume that after seeing the break-even points for the scenarios in Figs. 1 and 2, the practice decides that your clients’ willingness to pay for an abdominal ultrasound exam is underestimated. We now assume that $200 per exam is a reasonable price. We will also consider the same amount as Fig. 1 for variable costs ($40). In this scenario, 47 exams are necessary to break even on the purchase of this additional transducer (Fig. 3). Although this seems enticing, it is important to consider the likelihood that clients will pay $200 for a service not previously offered and realistically how many times per week, month, or year you would have performed this service if you had owned the transducer.

Similar analysis can be used when considering adding extra transducers when purchasing a new ultrasound machine. Usually, the cost of the transducer is somewhat less when purchased as a package deal, and it can therefore be tempting to

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**Fig. 1.** Basic break-even analysis: The purchase price of an ultrasound transducer to perform abdominal ultrasound is $7500. We assume a price of $100 per examination, and $40 variable costs to perform one examination. Contribution margin = $60 (amount of sales that will contribute to fixed costs). To determine the break-even point in units (scans), the purchase price ($7500) is divided by the contribution margin ($60). Given these assumptions, it would take 125 abdominal ultrasound exams to break even.

**Fig. 2.** Basic break-even analysis showing the effects of omitting variable costs using the same scenario as Fig. 1 (purchase price = $7500; client price of a single examination = $100). In this scenario, the same calculation shows that only 75 exams would be required to break even. Although this is still a substantial number of exams, it does not account for the variable costs involved, thereby underestimating the number of exams to break even on this purchase.

**Fig. 3.** Basic break-even analysis showing the effects of increasing client price from $100 to $200 using the same purchase price ($7500) and variable costs ($40/examination) as in Fig. 1. In this scenario, only 47 exams are necessary to break even on this purchase. Although this makes the purchase seem attractive, clients’ willingness to pay must be considered before assuming that this scenario will hold true within a practice.

**Fig. 4.** Costs of Ultrasound Training

<table>
<thead>
<tr>
<th>Costs of Ultrasound Training</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Assumptions</strong></td>
</tr>
<tr>
<td>Annual Production (Gross)</td>
</tr>
<tr>
<td>Salary or Guaranteed Minimum</td>
</tr>
<tr>
<td>Days per Year</td>
</tr>
<tr>
<td>Weekdays Off</td>
</tr>
<tr>
<td>Weekend Days Off</td>
</tr>
<tr>
<td>Total Work Days</td>
</tr>
<tr>
<td>Daily Veterinarian Compensation</td>
</tr>
<tr>
<td>Daily Veterinarian Production</td>
</tr>
</tbody>
</table>

**Ultrasound Continuing Education**

<table>
<thead>
<tr>
<th>Number of CE Courses</th>
<th>Tuition</th>
<th>$1,100</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Airfare</td>
<td>$500</td>
</tr>
<tr>
<td></td>
<td>Hotel</td>
<td>$135</td>
</tr>
<tr>
<td></td>
<td>Days Away From Practice</td>
<td>$255</td>
</tr>
<tr>
<td></td>
<td>Compensation/Salary Employee While at CE</td>
<td>$2,545.45</td>
</tr>
<tr>
<td></td>
<td>Daily Veterinarian Production</td>
<td>$1,455</td>
</tr>
<tr>
<td></td>
<td>Lost Revenue (Prod x days away for CE)</td>
<td>$14,545.45</td>
</tr>
</tbody>
</table>

**Total Cost of Training Excluding Marketing/Branding**

| $21,651 |

**Fig. 5.** Training costs associated with providing a new service (MSK ultrasound): Two CE courses are assumed necessary to acquire basic level of competence during year 1. Assumptions are highlighted, including annual gross production, annual vacation days, days on call, and costs associated with ultrasound CE courses. This information will be used to perform the break-even analysis shown in Fig. 5.
purchase “add-on” probes even when there is not currently a need for that transducer.

4. **Break-Even Analysis—Advanced Concepts**

For those prepared for more advanced break-even analysis, additional factors should be considered. For this portion of the presentation, we will consider the purchase of an ultrasound machine and assume that the practice/veterinarian desires to expand from primarily reproductive ultrasound to include MSK ultrasound. Because the practice area is changing from primarily reproduction to sport horse practice, they believe demand will change to support this type of service. The practice foresees gradual expansion into advanced MSK ultrasound over the next few years. This is supported by frequent requests of existing and new clients to perform such procedures. They are therefore evaluating the purchase of a high-end portable ultrasound machine that includes three transducers for basic and advanced MSK ultrasound and some abdominal exams for colic referrals. Based on their experience, at least two ultrasound CE courses are felt necessary to develop a basic level of competence in the first year. Although we are using ultrasound as an example, this analysis can apply to any type of new service.

The first consideration is the cost of training in the first year (Fig. 4). This includes not only the direct costs associated with CE courses, but also the opportunity costs associated with attending these CE courses (i.e., revenue you would have earned had you not attended the course). The opportunity cost in this example is 10 days of daily production, as-

### Break-even Analysis For Projected Profitability - Ultrasound Machine

<table>
<thead>
<tr>
<th>Variable Costs of Service and Equipment To Be Covered</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Technician</td>
<td>$26.00 per hour including benefits</td>
</tr>
<tr>
<td>For a total of</td>
<td>$6.60</td>
</tr>
<tr>
<td>2 Veterinarian</td>
<td>$30.00 % of procedure fee (20%)</td>
</tr>
<tr>
<td>3 Payroll Taxes at (Vet + Tech)</td>
<td>0.80% of total salary dollars</td>
</tr>
<tr>
<td>For a total of</td>
<td>$3.48</td>
</tr>
<tr>
<td>4 Misc. Drugs &amp; Prof. Supplies</td>
<td>$-</td>
</tr>
<tr>
<td>Total Variable Costs Per US Exam (Tech/Vet/Taxes)</td>
<td>$40.08</td>
</tr>
</tbody>
</table>

**Return on Equipment and Training**

<table>
<thead>
<tr>
<th>Number of Years of Proposed Equipment Life and Training Pay Off</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Obsolescence Factor at Plus Return on Investment</td>
<td>20.00% of total equipment cost</td>
</tr>
<tr>
<td>Total Equipment Cost</td>
<td>$90,000</td>
</tr>
<tr>
<td>Total Training/CE Cost (from Figure 4)</td>
<td>$21,651</td>
</tr>
<tr>
<td>Total Cost Equipment and Training</td>
<td>$111,651</td>
</tr>
<tr>
<td>Annual Return on Equipment and Training</td>
<td>$20,062.25</td>
</tr>
<tr>
<td>Estimated Additional Overhead Utilities</td>
<td>$-</td>
</tr>
<tr>
<td>Maintenance Agreement</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Taxes and Insurance (2%)</td>
<td>$1,000.00</td>
</tr>
<tr>
<td>Promotional/Advertising</td>
<td>$-</td>
</tr>
<tr>
<td>Total Other Fixed Costs</td>
<td>$2,000.00</td>
</tr>
<tr>
<td>Total Fixed Costs Per Year</td>
<td>$22,062.25</td>
</tr>
</tbody>
</table>

**Assumptions:**

- Total Fee Per Procedure
- To Be Charged
- Total Fixed Costs
- Total Variable Costs
- $30,105.97 of annual sales.

**Break-Even Point**

<table>
<thead>
<tr>
<th>Number of Procedures to Reach Break-even (Break-even Sales/fee per Procedure)</th>
<th>201</th>
</tr>
</thead>
<tbody>
<tr>
<td>Desired Profit Margin</td>
<td>15.00%</td>
</tr>
<tr>
<td>Break-even Fee Income Including Profit</td>
<td>$37,854</td>
</tr>
<tr>
<td>Annual Total Procedures</td>
<td>252</td>
</tr>
<tr>
<td>Number of Procedures to Reach Desired Profit Margin</td>
<td>1.0 per day</td>
</tr>
<tr>
<td>Break-even Profit Margin</td>
<td>275 days/year</td>
</tr>
</tbody>
</table>

Fig. 5. Advanced break-even analysis considers technician and veterinarian salary, payroll taxes, time to perform one examination, fixed costs, including machine and service contract costs, desired return on investment and CE/training costs (see Fig. 4), and desired profit margin. This scenario also assumes a 5-year equipment life and evaluates how many exams per year will be necessary to break-even over the equipment’s life; 201 annual exams are required to break even without considering profit margin and 252 annual exams are required when desired profit margin is considered.
suming all days away are work days. Given these assumptions (highlighted in yellow in Fig. 4), the total cost of attending two CE course is $21,651. This number might seem high, but keep in mind that it includes $14,545 of lost revenue while away from the practice. This is the opportunity cost of leaving the practice to obtain training and should be considered in break-even analysis.

Fig. 5 shows advanced break-even analysis for the purchase of the ultrasound system (essentially the addition of new ultrasound services). Costs considered in this analysis include veterinarian and technician salary, payroll taxes, time to perform an exam, fixed costs (machine and service contract costs amortized over 5 years), desired return on investment (machine and CE/training costs [see Fig. 4]) and desired profit margin. This scenario also assumes a 5-year equipment life. The output shows the number of annual exams necessary to break even over the equipment’s life (5 years) with and without consideration of desired profit margin (252 annual exams and 201 annual exams, respectively).

5. Equivalent Annual Costs—Comparison of Two Possible Purchases
Equivalent annual costs is a financial exercise to compare annual costs of two different units when purchase price and recurring costs differ. It is also helpful when the machines have different useful lives. Let’s say you have narrowed your search to two different units. Machine A is less expensive but unlikely to last as long (3 years vs 5 years) as Machine B. Machine A has a purchase price of $20,000 and Machine B costs $35,000 dollars. Both offer a 1-year warranty with service contracts available for purchase after year 1. Machine A’s service contract is $3000 per year but is only available for 2 years, effectively giving this machine a 3-year life. Machine B’s service contract is $3500 per year and is available for 4 years (effectively a 5-year life). We will present analysis (using present value and the annuity formula) to help decide which to purchase. This information is also useful in lease vs purchase decision.

6. Summary
It is hoped that this presentation will allow practitioners to add a new tool(s) to their toolbox when considering a new or replacement purchase or when considering the addition of new services to a practice. The basic version is a good place to start for those new to business concepts; while the more advanced version may be more attractive to those experienced with such concepts. The use of break-even analysis in any form is an important consideration when making such important practice decisions.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Transition From Solo Ambulatory to Brick and Mortar Practice: Work Smarter Not Harder

Tracy R. Walker, DVM

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1. Introduction

The decision to expand your practice can be exciting and overwhelming at the same time. As a solo practitioner you have enjoyed the simplicity of working by yourself, making your own decisions, and keeping your overhead at a minimum. This presentation will highlight my personal experiences transitioning from ambulatory to brick and mortar practice. I started my practice ten years ago in a rural area with no prior equine services. While building my equine practice I also worked locum and part time at a small animal hospital. In 2015, the small animal hospital closed and I purchased property to expand my ambulatory practice with a large animal haul-in facility and small animal hospital. This presentation will focus on the transition and expansion of the large animal practice.

2. Is Transition and Expansion Right for You?

First, you must decide whether transition or expansion of a haul-in hospital will be of benefit to you personally. Approach the decision in two parts: subjective or emotional considerations, objective or financial considerations.

3. Subjective Evaluation

Are you happy and satisfied with your current working situation? List what makes you happy and things you would like to change about your current working situation. Consider your personal aspects such as quality of life, working hours, family, personal time, and income. It is equally important to consider professional satisfaction. Are you able to attend quality continuing education? Are you able to purchase new equipment necessary to practice at the level you wish? And lastly, are you planning appropriately for retirement? Are you prepared for the increased responsibility of an expansion, management of more employees, and increased debt load? Do you really want to do this?

4. Objective Evaluation

How much is this going to cost you? Can you afford to do this? How will you pay for this and will it be worth it in end? Enlist a CPA or MBA to help with the objective measures. Evaluating the financial commitment is enlightening to say the least. Start by creating a budget for land purchase, building construction, and/or renovation. Practice historical data can be used to create reasonable projections. Create a 60-month financial projection. These projections will take into account growth of income,
Draft a business plan to define the goal of the project. The Small Business Administration has several online tools and articles to help draft a plan.\(^1\) The business plan is a working document that will define a clear goal while providing a guide and timeline for the project as it progresses. A current market analysis will be part of the business plan. Several resources for companion animal market analysis are available. Information for quantitative large-animal market analysis can be difficult to find. The American Veterinary Medical Association (AVMA) Report on Veterinary Practice Business Measures is published every 2 years and can be purchased on the AVMA Web site.\(^2\) The National Agricultural Statistics Service is a free resource of animal population census that can be broken down by county.\(^3\) A market analysis should also include evaluation of competition. Mapping other existing veterinary practice locations, competing practice coverage areas, and your existing practice coverage area will help determine an ideal location for your haul-in location.

Armed with this information, you can objectively evaluate the project. Is the project financially feasible? Can you afford to do this?

5. **Now Make it Happen**

Once you have made a decision to add a building, begin preparations for a loan application. We began by paying off any debt and developing a cash savings. We re-evaluated our bookkeeping system to more easily separate and track new income sources and expenses.\(^4\) In addition, the current business structure was re-evaluated and the business was restructured from a sole proprietorship to a professional limited liability corporation. The advantages and disadvantages of the various business structures will vary by state. I consulted both a lawyer and accountant to determine whether restructuring was to my benefit. However, in my case, restructuring was of benefit mainly for liability reasons.

Actively search out property and make inquiries about potential real estate locations. In my area, good property rarely gets listed on the real estate market. I encourage you to look at both land and existing structures. Many existing structures can be easily converted to a suitable practice location with reduced cost compared with new construction. Beware of local ordinances and permitting when searching for a suitable piece of property. Many cities have restrictions against livestock, barking dogs, and other laws that may affect the suitability of certain locations. I actively searched existing listings and approached three unlisted properties. Ultimately, the property I chose was an unlisted existing commercial building with accessibility for trailers and suitable geographic location.

Design of the property can be done by you or you may hire an architect. Given the overall budget of my project, I chose to design the property myself. This may or may not be the best decision for you, depending on your experience or availability to oversee the project. Regardless, you should research design ideas. There are several printed and online publications that are helpful to review for design ideas.\(^5,6\) Using an online design app\(^7\) will help you create to scale drawings and three-dimensional drawings of your project. My entire project was designed on a simple app with overlays for electric, plumbing, ventilations, and security/information technology as needed. The location was suitable for an equine haul-in facility and a small animal hospital.

Does this all seem like “putting the cart before the horse?” Completing all of these pre-requisites is exhausting and time consuming. However, armed with a complete business plan, you will confidently approach the financing. In my case, a well-organized business plan resulted in several banks competing to finance the project and a quick 30-day closing.

6. **The Transition**

**Marketing:** **Feed the Need for Information**

How you market this transition to clients is essential to their retention. Create a marketing calendar that follows the construction/renovation timeline. It is important to provide appropriate information in a timely manner. Our initial announcements were specific about services but vague on time. We advertised the opening of our hospital location in the Spring and were careful to avoid specific dates. Overestimating the opening date or constant delays can deter from the excitement of the project.

**Leak Information**

Start by personally talking to your best clients while on routine farm calls. This builds loyalty as these clients are assured that you are not abandoning them and also honored that you let them know first. We began leaking information about location, plans, and additional services as soon as we closed on the property.

**Formally Announce**

Compose a letter to your top clients. Include the exciting news, location, and new services that will be offered and assure clients that farm service will remain available.

**Create Buzz**

Make an announcement in your practice newsletter or practice blog. Use social media to your advantage. Collect photos from day one of construction and planning. Within a few months of your move in date, post regularly (twice weekly) with photos.
and construction updates, new service updates, and snippets on design or new hours to be offered. We collected construction photos for several weeks before posting them. Then we scheduled postings on social media every other day during the 6–8 weeks prior to our move. The repeated postings with drastic before and after changes created a lot of response on social media.

**Web Site**
Update your Web site to include new location information, new services, and a pictorial tour of the progress.

**Postcards**
Print a postcard with a map, hours, and phone numbers to the new facility. Beginning approximately 60 days prior to moving, this was handed directly to clients on farm calls. The postcard was designed to be placed on a refrigerator and much larger than a business card to prevent loss. Clients were relieved to see the written format as if it validated the changes.

**Digital Picture Frame**
Approximately 60 days prior to moving, we placed a digital picture frame with construction photos, PowerPoint slides, and information on the counter at the small animal clinic that was closing. This single tool was very effective in capturing attention of existing clients as they came, generating questions, and conversation about the new facility.

**Open House**
Plan an open house for about a month after you get moved in. You can begin advertising the open house as you get closer to your move-in date. Allowing a few weeks between the move-in and open house will allow you to finish projects, landscaping, and details. We had our open house and grand opening approximately 6 weeks after our move-in date. An invitation was mailed to our top clients. A press release was provided for the local newspaper. The primary source for advertising our open house/grand opening was via Facebook. Approximately 300 people attended our open house on a weekday afternoon!

7. **Addressing Client Concerns**
It is important to address the specific concerns of clients as you journey through this process. Most clients were immediately concerned that we would cease farm calls. We were quick to personally assure clients that we would continue to offer the same services with increased availability via two doctors. This was reinforced in all of our marketing material and in personal communications. We approached these concerns as a great opportunity to educate owners about the new options that this transition would bring.

Many clients were concerned that the practice would become too large and that our personal communication would be affected. Large-animal clients were very comfortable speaking with one particular technician who had been with the practice for 10 years. As part of our transition, this technician was shifted to a practice manager and large-animal coordinator.

As we combined the practices, we retained two phone numbers: one for small animal and one for large animal. Both phone numbers ring to the same facility but are directed to their respective departments. This has allowed large-animal clients to bypass the small-animal reception desk and go directly to the large-animal coordinator. Hearing the familiar voice of the large-animal coordinator has helped clients accept this growth and change.

8. **How Have We Encouraged Clients to Haul In?**

**Communication and Staff Training**
It has taken staff, including myself, almost a year to routinely offer haul-in as an option for seeing a patient. Regardless, it is important for staff to offer this each time they speak with a client. The client may not be interested in haul-in for this appointment but it is also a chance to reinforce this as an option.

**Availability**
We have become much stricter about our ambulatory/farm call schedule and reducing crazy cross-practice days. Clients are encouraged to haul-in for faster availability.

**Reduced Cost**
Some practices will charge an office call in addition to an exam fee for patients hauled to the clinic. We do not charge an office call for patients hauled to the clinic, and this results in a reduced charge to come to the clinic and acts as an incentive to clients.

**Increased Quality of Care**
This is obvious to us as veterinarians, but not to our clients, who have never had this option. We are sure to explain to clients that we can offer better care for certain cases.

**Service Limitations**
Some services are only offered in the clinic.

**Minimal Boarding Cost**
We have intentionally kept our boarding fee very reasonable. We have been pleasantly surprised by the number of clients who have chosen to board patients for extended periods for rechecks and bandage changes. This reduces our time on the road for rechecks and bandage changes.
9. What I Did Not Expect....

It took me almost 9 months to be comfortable and efficient using the new facility. Old habits are hard to break! I found myself going to the truck to retrieve supplies because I knew exactly where to find them. The addition of new storage space was at times overwhelming and we re-organized cabinets and drawers several times. Now that we are settled in, the design of the space has worked very well.

Establishing traffic flow of equine haul-in patients was a new challenge. Equine clients would tend to bypass the reception desk and walk directly into the equine treatment area. Many of our clients have never seen an equine hospital and are genuinely curious about the facility and the cases we see. Satisfying the curiosity of clients and showcasing the facility had to be balanced with a professional atmosphere and client/patient privacy in the treatment area. We addressed this by adding signage to direct trailer parking and registration prior to unloading. Receptionists are also instructed to politely intervene if a client is seen walking or driving directly to the treatment area doors. In addition, we regularly lead tours through the building to highlight the facility and expanded treatment capabilities. I enjoy working up lameness cases again. In my practice area, a flat area is hard to find, let alone a suitable place to trot out a horse. I have quickly become spoiled by the paved parking lot for trot out. I also underestimated the luxury of watching a lameness from a consistent location and position at the hospital.

The time required for me to dedicate to practice management was sorely underestimated, particularly in light of the increased appointment demand by clients. The growth of the practice has resulted in more appointment demand and longer appointment times as I see more complicated cases. Additional staff were hired to maximize doctor time. The ambulatory practice had previously employed two veterinarians and two support staff. The current practice employs two veterinarians and eight support staff, including a practice manager who handles the day to day bookkeeping and employee management. However, the increase in the number of employees requires a clearly defined infrastructure of procedure, policy and maintenance protocols that are continually drafted and modified to maintain our desired level of client service and patient care. In addition, I have outsourced many tasks such as website management and IT services.

10. The Results

The large animal practice revenue has increased by 27% since the expansion. Our projections on haul-in patients were modest at an average of two patients a week during the first year. We are well over our projections, averaging almost one haul-in patient per day. The small animal practice is thriving and revenues have been important to further expanding staff and equipment. Most importantly, I personally feel inspired to practice again and I’m no longer suffering from burnout. I have time to pursue both quality continuing education and personal time. And, I would do it all over again.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Author declares no conflicts of interest.

References
Transitioning Into Management for the Associate, Owner, or Partner

Mike Pownall, DVM, MBA

1. Introduction

Transitioning into a management role can be as professionally and personally satisfying as that of a veterinarian. The flip side of course is that without careful planning and consideration the transition into management can be a maze of dead ends and frustration. The goal of this presentation is to outline key areas to consider before and during the move to management helping to ensure a smooth transition.

The first challenge a new manager or leader will find is that the mindset needed for success in either is very different than that of a clinical veterinarian. In the field, or clinic, we strive to minimize the gray areas of a situation to get to the most accurate diagnosis and treatment plan. Of course, having black and white answers is often aspirational rather than a reality, but the aim to find a clear path to an answer is our optimal goal. Meanwhile, in management we are faced with shades of gray. During my MBA studies we used to joke that the best way to answer a question is with “it depends.” It does truly depend on the situation. Most of the everyday challenges in management are related to people; staff, clients, co-workers, and suppliers. There is never a one-size-fits-all solution when dealing with people because they all bring their own perspectives on life in any given situation. The same could be said about dealing with horse owners, but at least in a veterinary situation we have a diagnosis to guide us in treatment and prognosis. One is not harder than the other, they are just different. Many veterinarians that have transitioned into management positions have an easier time with the financial performance of their business because dealing with numbers and spreadsheets are in line with the laboratory work and diagnostics we use in veterinary medicine.

If you begin to devote more and more time to managerial duties, then the challenge becomes adapting your mindset to deal with clients when you are seeing patients. Things tend to happen quicker when you are a manager, and you can dictate the flow of your day. Managers can block off time to focus on tasks or schedule meetings at their convenience. When animals and clients are involved the pace of the day can shift dramatically. When I have to go on the road I have to be very conscious of not becoming impatient because I am not in control like I am back in the office. This impatience lasts a short time because within a couple of appointments the joy of client relationships and the satisfaction of helping horses takes over and I am in the moment.
This vet/business duality is one of the biggest speed bumps veterinarian discover in their new role of managers. Balancing the needs of the business with those of their clients on the same day is extremely challenging. I found myself thinking of business when dealing with clients and then feeling like I was not following up on clients when I was doing managerial work. Ideally, it is best if management time and vet time can be separated by working set days on the business, and set days as a vet. Keeping the schedule is important for your coworkers so that they know to wait to discuss non-urgent business issues, and you are scheduled accordingly.

Compensation for management responsibilities can become a huge issue when there are business partners involved. Veterinarians often gauge the value they offer to a business by how busy they are, or the amount they bill. This is particularly important when veterinarians are compensated based upon production. When the veterinary manager stays in the office they lose the ability to earn compensation because they are not billing clients. A management fee must be considered for vet managers who work on a commission system. The management fee should be consistent with the market rate for a veterinary manager for a similar practice. Depending on the size of practice this might be a step down or up in pay; the larger the practice the more a manager would be paid. As an owner you will see an increase in year-end owner distribution because if you are doing your job well the business will be growing revenue and profit. There may need to be a performance bonus in the compensation plan for an associate if they are taking on managerial responsibilities, given that they will not have access to owner distribution.

Business is similar to veterinary medicine in that a good education goes a long way. Unlike a veterinarian, a business manager does not have to be licensed to perform their duties but they should consider some form of education to be able to understand their business and communicate with others in the business world. A good business education is based upon evidence-based research and offers the student a comprehensive overview of numerous subjects. It is not enough to know a lot about one or two subjects, rather like veterinary school, the student should learn about different elements of business and how they interact and support each other. Just like we learned anatomy and pharmacology before we learned equine lameness and surgery, a good business education will integrate various subjects into a broader-based program. This does not mean that everyone who wants to manage their business needs to complete a MBA degree, rather they should explore the various options available through professional associations, online courses, community college courses, or more formal business education programs.

Once you are established in your role as a manager of your practice the final thing to consider is whether you are doing a good job. Similar to metrics we use to identify health and sickness in animals, a business needs key performance indicators to track the health of a business. Some of these metrics could be revenue growth, increased profitability, lower staff turnover, or increased employee engagement. Whichever metrics are used they should be consistent with the overall goals of the business and measured on a regular basis, which could be quarterly, semi-annually, or yearly.

Managing a veterinary business can be extremely satisfying. Involvement of a veterinarian in management offers an excellent opportunity for someone who has diagnosed and treated animals to have an influence how to offer excellent medical care while operating a successful business. Though there will be challenges in the transition, a methodical approach to change in roles will help ensure success.

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Conflicting Perceptions of Practice Ownership:  
Survey Results From AAEP Listserv Members in 2014

Amy L. Grice, VMD, MBA

The 2014 AAEP Listserv Survey examined the perceptions of both associates and practice owners about practice ownership. Several broad themes emerged from the results: a disparity in beliefs about transitions of ownership, the importance of developing a transparent path to ownership, and the importance of practice culture. Strategies for succession need to address these key components. Author's address: PO Box 192, Virginia City, MT 59755-0192; e-mail: amyvmdmba@gmail.com. © 2016 AAEP.

1. Introduction
Equine practice owners commonly experience difficulty finding associates willing to stay long term in their practices and interested in buying an ownership interest when the current practice owner(s) wish to sell shares. This complicates the exit strategies of the current owners, given that the best buyer is most likely one that is already well established within the practice.

In order to explore the perceptions of equine veterinarians about their work environment, an online survey was conducted among practitioners to identify the most pressing concerns of practitioners with regard to their business and professional life. A series of questions within the survey explored the theme of ownership transitions.

2. Materials and Methods
An online survey of equine veterinarians was conducted in the fall of 2014. The survey research design included the collection of both quantitative and qualitative data. A link to the survey was posted on the listserv of the American Association of Equine Practitioners (AAEP) and the Equine Clinicians Network. The initial survey was limited to those practitioners whose practice is >75% equine, and was closed after a week of responses. Upon reviewing the raw results, a problem in data collection was discovered. Due to defects in the functioning of the survey, some respondents were not offered the full complement of survey questions. Consequently, a repaired version of the survey that included the missed questions was posted to both listservs in late November 2014 with an explanation and invitation to the affected respondent segments. In addition, due to requests from listserv members, those providing <75% equine services were invited to participate in the second survey. In order to have valid data, previous (redundant) responses from duplicate Internet Protocol addresses were discarded. Responses from both surveys were then compiled additively.
3. Results

A total of 516 veterinarians responded to the survey. At the time of the survey, there were 1520 AAEP members on the General listserv. It is likely that there is significant overlap with members of Equine Clinicians Network, but this is not known with certainty. If considering only the membership of the AAEP General listserv, this is an approximately 33% response rate, and would roughly yield a 95% confidence interval. When considering the results of the survey, it is important to remember that the population surveyed was those members who are active on the listserv, which, by necessity excludes the members not utilizing this mode of communication. Important differences may be present between the non-listserv practitioners and those surveyed.

Survey respondents differed in some demographic characteristics from the AAEP membership reported in the 2014 AAEP Annual Report. Respondents were made up of 38.4% solo practitioners (AAEP 39%); and 61.6% group practice members (AAEP 19.8% Associates, 15.3% Practice Ownership-Partnership, 6.4% No Response). Of the group practices, 50.6% respondents worked in practices with two to six veterinarians, and 11.0% worked in practices with seven or more veterinarians. There were 60.4% female (AAEP 47%) and 39.6% male (AAEP 53%) respondents. 44.9% of survey respondents graduated between the years 2004 and 2014, and 55.1% graduated in 2003 or before.

Survey responses were obtained from 297 equine veterinarians working in group practices. Of this group, 82.2% practiced in groups with two to six veterinarians (Small Group) and 17.6% practiced in groups of seven or more veterinarians (Large Group). Associates made up 57.5% of respondents, and partners/shareholders 41.4%, with the remainder consisting of interns/residents.

Associates

In the section of the survey exploring perceptions about practice ownership, associates were asked if they were interested in practice ownership as a partner or shareholder. A strong majority (82%) answered “Yes,” with only 18% indicating no interest. Small Group associates were somewhat more interested in ownership (84%) than Large Group associates (76%) (Fig. 1).

Despite a strong interest in practice ownership among associates, they are not generally well informed about practice finances. There was a disparity in the responses of Small Group practice and Large Group practice associates regarding the sharing of practice financial data, as demonstrated in Figure 2. It was considerably less likely that associates at large practices were privy to the practices’ financial data.

Similarly, understanding the path to partnership/ownership was considerably more likely among Small Practice associates than those employed at Large Practices (Fig. 3). Importantly, 31% of Small Practice associates and 58% of Large Practice associates did not understand the path to becoming an owner or partner in the practice, and only 14% of Small Practice associates and none of the Large Practice associates understood “very much.”

Associates also displayed little confidence that they would be offered partnership or ownership of shares, as shown in Figure 4. Less than 20% were either “Very confident” or “Confident” in an offer, and there was much less confidence among associates employed at Large Practices than at Small.

Small Practice–and Large Practice–associates showed little difference in their responses to the
question, “How important have the following factors been in decreasing your confidence in being offered partnership or ownership of shares?” Both groups’ respondents chose “Practice Culture” (48%) and “Price” (47%) as “Very Important” or “Important” more often than other factors, followed closely by “Financial Feasibility” (45%) (Fig. 5).

Associates were asked, “If you are not offered partnership or ownership of shares in the next several years, what is the likelihood of you staying in your current position?” (Fig. 6) If the responses, “Extremely Likely”, “Very Likely”, and “Likely” are considered additively, Large Practice associates (44%) are more likely to stay than Small Practice associates (34%). In fact, 37% of Small Practice associates responded that they were “Very Unlikely” or “Extremely Unlikely” to stay at their current position if not offered an opportunity for equity. This contrasts with the 17% of large practice associates who responded in an equivalent way. However, 39% of Large Practice associates vs 28% of Small Practice associates were “Likely” to leave their current position if not offered an opportunity for an ownership stake. When adding “Extremely Unlikely”, “Very Unlikely”, and “Unlikely” responses, 56% of Large Practice associates and 67% of Small Practice associates indicated they are likely to leave their current position if their desire for a stake in the practice is not met.

Practice Owners (Partners/Shareholders)

Group practice owners were asked about their desire to sell an ownership interest in their practice to one or more of their associates. Large Group practice owner respondents were much more likely to desire to sell shares or take on a partner (93%) than Small Group practice owners (59%) (Fig. 7).

Although a majority of all respondent group practice owners indicated a wish to sell shares or add partners, only about half of those who indicated this desire had a degree of confidence that they would be successful in completing the transaction. Although no Small Group practice owners were extremely confident they will be successful in selling shares to an associate, 14% of Large Group practice owner respondents held this view. An equal percentage of Large Group practice owners were pessimistic about their chances for sale of equity (Fig. 8).

Owner respondents were given an opportunity to share their reasons for their confidence or lack of
confidence through an open-ended qualitative question. Responses fell into three general categories:

1. Perception that associates/younger generations of veterinarians are not interested in ownership
2. Concern that practice ownership is not affordable due to student loans held by many veterinarians
3. Difficulty in establishing value of practice that is acceptable to both parties.

4. Discussion

Many practice owners have made the sale of their practice equity a key component of their retirement planning. Failure of the ability to harvest these assets can have serious financial ramifications for these practitioners’ retirement portfolios. Difficulties in selling shares in a practice can flow from a lack of communication, frequent turnover of associates, or trouble in establishing a practice value that motivates both the seller and the buyer to make a transaction.

The results of this survey demonstrate a clear lack of communication between associates and owners. The majority of associate respondents are interested in acquisition of shares; the seriousness of this desire is borne out by the high numbers that intend to leave the practice where they are currently employed if they are not given the opportunity to buy into the business. Meanwhile, many practice owners have the perception that associates are not interested in ownership. This discordance can be bridged by education and communication.

Communication of the path to ownership is essential for associates to understand expectations. Will an invitation to become a partner or shareholder follow achieving a specific gross revenue figure, demonstrating certain work behaviors, being employed for a certain number of years, or bringing in a certain amount of new business? If an associate achieves those things, but is not well liked personally by the practice owner, will this prevent an offer of shares? Will the owner communicate clearly if ownership is not and will never be an option, based on certain behaviors or personality traits that have been observed in the associate? If partnership is offered, what is the process? How is the value of the practice determined? Will the financing be inside or outside the practice? Will a down payment typically be required? Associates that do not understand the process of becoming an owner may seem to have no interest, but they may in fact think that their employers are not interested in selling since they have not been engaged in conversation about it.

Bringing an associate into an equity position is ideally a several-year process that includes financial and business management education. Learning how to handle difficult personnel or client interactions; becoming familiar with branding and marketing; and understanding the concepts of revenue, expenses, and net profit are first steps on the path to ownership. This type of education is valuable for associates as well, even if they choose to remain employees rather than owners for the course of their career. Sharing increasing amounts of financial data and delegating management tasks are next steps. Finally, explaining the mechanics of the valuation and purchase of shares fairly early in the progression will allow a thoughtful deliberation. The results of the survey show that this approach is rarely followed. If more communication about the path to ownership occurred, perhaps even more associates would be interested.

Finding associates that will remain employed in their practice long term is a common problem for some practice owners. Because the most readily accessible buyer is one that is already well established with the practice, this complicates the exit strategies of these practitioners. It is also disruptive to clients to have to frequently adjust to a new care provider; and expensive for a practice to find, train, and market each new hire. It is not uncommon for practice owners to feel like they simply cannot find the right candidates and to be disappointed in the young veterinarians they meet. Although it is a fact of the times we live in that dual-career couples frequently must move for a spouse’s promotion, success in retaining associates also requires a number of elements: having a clear mission and vision for the practice, understanding partner values so one can hire in alignment with them, having a practice culture that is appealing to new hires and in alignment with their values, understanding generational and gender differences in younger veterinarians, and being committed to associates’ professional development.

As reported previously, of the 185 solo practitioners responding in the 2014 AAEP Listserv survey, 75.4% had previously worked in a group practice (excluding internships). Of these, 77.8% were past associates and 22.2% had been owners or partners in group practice. The survey asked these solo practitioners, “What is the primary reason you are now in solo practice?” Dissatisfaction with practice cul-
Culture was the most chosen response among respondents that were formerly employed as associates. Of the respondents previously employed as partners or shareholders in a group practice, 26.7% cited partner/shareholder discord as the primary reason they are now a solo practitioner. 3 A practice culture that is in alignment with the veterinarian’s values is essential for professional contentment and long-term employment. Understanding values is essential to hiring successfully. Individuals absorb their values from their earliest experiences in their nuclear families, and these core beliefs will guide them through their lifetime. These are the personal truths that feel undeniable. Values are the core of identity of individuals and organizations; they are principles, beliefs, and philosophies that shape what you believe is right. In a veterinary practice, values mirror the owners’ nonnegotiable beliefs and give birth to the culture. When practice owners continually demonstrate and communicate those values, they provide a guideline for the expected behaviors of the entire veterinary team. It is essential that practice owners hire to support their values, because people with different values feel as strongly about their core beliefs as others do about theirs. When the values of the owners and the employees are not aligned, none will be happy.

Organizational culture is defined as the common organizational mindset, and encompasses the philosophy, attitudes, feelings, values, and behaviors of the group and its members. It is based on shared attitudes, beliefs, customs, and written and unwritten rules. Throughout the ages, each generation has struggled to understand the perspective of the generation following it. Society changes, and as a result the values that children absorb from the world around them change along with it. If a practice’s culture is inflexible and leaves no room for new ideas and approaches, it should be no surprise that a generation with different life goals will opt out and seek a different home for their career. It is important to remember that experienced, mature practice owners and new veterinarians seeking positions as associates both share many of the same goals: they want to be successful in their profession, have financial security, make a difference in the lives of horses and the people who own them, and feel good about how they are spending the days of their life.

Establishing the value of the practice to buy or sell shares can be fraught with emotion, but in fact it is simply mathematical. Many, if not most, equine practices are valued by the discounted earnings or cash flow method, which is based on the principle that the total value of a business is the present value of its projected future earnings. The net present value for the sum of the projected earnings is determined by using an appropriate discount rate. The worth of a business is almost entirely made up of its ability to produce cash (profit). A buyer is essentially purchasing a future stream of income. The value of tangible assets is mostly in what cash they help produce for the practice, given that the fair market value of used equipment is quite low in the veterinary industry. In many negotiations, the practice owner has an inflated idea of the worth of the practice, and this may discourage an associate who is a potential partner. In most sales of shares, the ownership return should service the debt to purchase it, leaving the buyer’s income for effort as a veterinarian intact. In other words, the new owner should be paid for being an owner as well as a veterinarian. The ownership portion should be allocated to servicing debt, whereas the remaining veterinarian portion is used as income. Consultation with appropriate legal and accounting professionals is recommended.

Bringing associates wanting to buy shares together with owners wanting to sell shares should be possible and yield successful partnerships if these tenets are followed by both parties:

- Regular and transparent communication of professional goals from the earliest stages of an associate’s career
- Establishment of an inclusive, positive, flexible, and vibrant practice culture
- Realistic valuation of a practice’s worth that embraces the need for a willing buyer and willing seller

Continuing to hope for a different outcome while refusing to change what is not working is a recipe for failure. Hope is not a strategy. As William Ward said, “The pessimist complains about the wind. The optimist expects it to change. The realist adjusts the sail.”

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References

Positron Emission Tomography: A Promising Modality for Imaging the Equine Distal Limb

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Positron emission tomography (PET) can be used safely to image the equine distal limb and presents promising clinical and research applications. Authors’ addresses: University of California—Davis, School of Veterinary Medicine (Spriet, Espinosa, Katzman, Galuppo), and College of Biomedical Engineering (Kyme), Davis, CA 95616; Brain Biosciences, Inc., Rockville, MD 20852 (Beylin); e-mail: mspriet@ucdavis.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction

Positron emission tomography (PET) had never been performed in the horse mostly for technical and logistical reasons. Recently designed portable PET scanners now make it feasible to image the equine distal limb.

2. Materials and Methods

Six horses were imaged with PET under general anesthesia, three using 18F-fluorodeoxyglucose (18F-FDG), a soft tissue marker, and three using 18F-sodium fluoride (18F-NaF), a bone marker. Images of both front feet and fetlocks were obtained in all horses. Carpal and tarsal images were also obtained in 18F-NaF-imaged horses. Computed tomographic, standing magnetic resonance imaging, and scintigraphy were also performed.

3. Results

Lesions detected with the 18F-FDG scans included lysis of the flexor cortex of the navicular bone, lesions of flexor tendons and suspensory ligament, and abnormal uptake through the lamina of a laminic subject. The 18F-NaF scans demonstrated focal uptake in ligament attachments and subchondral bone where lesions were not identified using other imaging modalities. 18F-NaF uptake was also present in some osteophytes and enthesophytes. The radiation exposure was slightly higher than with 99mTechnetium scintigraphy but remained reasonable.

4. Discussion

PET images of the equine distal limb up to the carpus/tarsus were obtained easily using a portable scanner. 18F-FDG scans provided soft tissue information potentially useful for tendinopathy and laminitis research. 18F-NaF scans allowed differentiation between active and inactive osseous lesions, and highlighted lesions not detected using other imaging modalities.
Acknowledgments

This study was funded by a grant from the University of California, Davis, Center for Equine Health. A manuscript regarding the 18F-FDG PET data has been submitted to Veterinary Radiology and Ultrasound. A manuscript about the 18F-NaF PET data is currently in preparation.

The protocol was approved by the IACUC of the University of California, Davis.

Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

Brain Biosciences, Inc. has developed and manufactured the PET scanner used in this study (PiPET 10). Dr. Beylin is a shareholder and employee of Brain Biosciences, Inc.
Ultrasonographic Diagnosis of Carpal Collateral Ligament Injuries in 20 Horses (2000–2015)

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Carpal ultrasound is useful to diagnose collateral ligament (CL) injury even when there is no palpable joint instability. Medial collateral ligament (MCL) injuries seem to be more common than lateral collateral ligament (LCL) injuries and can result in varus deformity. Authors’ addresses: William R. Pritchard Veterinary Medical Teaching Hospital (Vanslambrouck); Department of Surgical and Radiological Sciences (Whitcomb, Vaughan, Galuppo), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; e-mail: lotharvanslambrouck@hotmail.com. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Ultrasound has been used to diagnose CL injuries in many joints in the horse; however, minimal information is available about carpal CL injuries.

2. Materials and Methods
Retrospective analysis of medical records identified 20 horses with ultrasonographic evidence of carpal CL injuries from 2000–2015.

3. Results
Injuries involved the MCL (n = 18) and LCL (n = 4). Two horses had biaxial injuries. Horses ranged in age from 2–26 years. Fourteen horses were used for pleasure, general use, or were retired. All but two horses had acute onset of clinical signs due to trauma, (n = 7) anesthetic recovery (n = 6), or unwitnessed events. Clinical findings included carpal swelling (n = 19), lameness at the walk (n = 11), varus deformity (n = 3), and palpable joint instability (n = 3). Ultrasonographic lesions were graded as mild (n = 2), moderate (n = 4), and severe/ruptured (n = 16). Ruptures most often involved the MCL insertion (8/10). Abaxial tearing was seen in 8/11 horses with proximal MCL injury. Radiographs revealed avulsion fractures (n = 10), osteoarthritis (n = 11), and joint instability (n = 5). Carpal arthroscopy and standing removal of an avulsion fragment were performed in one horse each.

4. Discussion
Ultrasound documented the extent and severity of carpal CL injuries and may be preferable to stress radiography. MCL injuries seem to be more frequent than LCL injuries and can result in the development of carpal varus deformity.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Research Abstract—for more information, contact the corresponding author

NOTES
A Review of the Complete Ultrasound Examination of the Intersesamoidean and Straight Sesamoidean Ligaments

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Ultrasound examination of the intersesamoidean ligament and the straight sesamoidean ligament in conjunction with a thorough knowledge of the normal anatomy and anatomic variation as well as the appearance of abnormalities affecting these ligaments can allow diagnosis of injuries prior to magnetic resonance imaging or provide continued monitoring of injuries diagnosed with MRI. Authors’ addresses: Equine Diagnostic Imaging, Archer, FL 32618; e-mail: equinedxim@yahoo.com. *Corresponding author; †presenting authors. © 2016 AAEP.

1. Introduction

With the use of magnetic resonance (MR) imaging (MRI) certain types of injuries are frequently seen affecting the soft tissue structures in the palmar fetlock region. Following acquisition of an MRI study, evaluation of the signal pattern within a soft tissue injury present on the MR images can be used to determine whether the injury can be detected with ultrasound. Certain signal patterns, in general, equate to detectable echolucencies on ultrasound when imaging tendons and ligaments. Of the structures in the palmar fetlock region, the intersesamoidean ligament (ISL) and straight sesamoidean ligament (SSL) present with injuries that can be identified on ultrasound. However, in certain cases these injuries are diagnosed with MRI due to the technical difficulty of imaging this region with ultrasound in conjunction with the complex anatomy. More specifically, this circumstance most frequently occurs with injury to the ISL/SSL at the transition point between the two ligaments. This area can be difficult to image with ultrasound for a number of reasons. The ergot can be an impediment, depending on the size, as can the fetlock conformation. A greater curvature of the structures on the palmar aspect of the limb due to the conformation increases the difficulty in accurately imaging this region with ultrasound. Furthermore, the ISL and SSL are deep to the flexor tendons, which increases artifacts and in certain cases requires a lower frequency when compared with imaging the more superficial structures, especially if clipping of the hair is not possible. The use of a lower frequency creates lower-resolution images, sometimes decreasing the conspicuity of subtle lesions. The ISL proximal to the sesamoid bones seems to be less frequently affected when compared with the distal ISL and the SSL. In general, the proximal ISL is often not examined routinely for this reason, and consequently some examiners feel less confident when imaging this region and fewer abnormalities are detected. At the level of the sesamoid bones the ISL fibers curve along the axial-palmar surfaces of...
the sesamoid bones, which requires a different technique for imaging this region compared with the ligament fibers that are located on midline. The necessary examination technique in conjunction with the anatomic characteristics affecting the ISL and SSL require that specific attention be paid to this region when imaging these structures with ultrasound. Incorporating anatomic knowledge and ultrasound skills as well as an understanding of pathologic change is necessary to perform a complete examination of this region. This paper reviews the anatomy and the technique for the complete ultrasound examination of the SSL and ISL while presenting the more-frequent types of pathologic change that can be diagnosed using ultrasound.

2. Basic Anatomy

The ISL and the SSL lie deep to the flexor tendons and are continuous with each other (Fig. 1). The ISL begins proximal to the proximal sesamoid bones, forming the proximal scutum, and continues as the SSL at the base of the sesamoid bones. The SSL then inserts distally on the middle scutum at the proximal palmar aspect of the middle phalanx. The ISL is composed of thick collagen fibers that cover the entire palmar and axial surfaces of the proximal sesamoid bones in a concave shape to allow the flexor tendons to glide across the fetlock region. The ISL is thicker on midline as it attaches between the sesamoid bones and then fans out gradually becoming thinner as it attaches to the more axial-palmar surfaces of the proximal sesamoid bones.

The proximal scutum begins at the apex of the proximal sesamoid bones and continues distal to the base of the sesamoid bones as the origin of the distal sesamoidean ligaments, including the SSL. As the SSL continues distal from the sesamoid bones, it becomes a trapezoid shape, with the dorsal margin lying against the palmar/plantar recess of the metacarpophalangeal/metatarsophalangeal joint. The palmar/plantar aspect of the ligament widens as it contacts with the deep digital-flexor tendon and comprises the dorsal margin of the digital sheath at this level. The SSL becomes triangular in shape between the oblique sesamoidean ligaments with a dorsal fiber bundle or sagittal part that can appear separate at the apex of the triangle. When the separate dorsal fiber bundle or sagittal part inserts more distally with the oblique sesamoidean ligaments on the palmar/plantar aspect of the proximal phalanx, the SSL takes on an oval shape until it becomes more triangular as it merges with the axial ligaments of the proximal interphalangeal joint and the branches of the superficial digital flexor tendon to become the middle scutum. The proximal SSL has a more heterogenous appearance with evident connective tissue that dissipates as it continues distally creating a more homogenous appearance immediately proximal to the middle scutum. However, the fibrocartilaginous area of the middle scutum creates heterogeneity within the middle scutum on midline at the insertion on the middle phalanx.

3. Equipment

The ultrasound examinations were performed with a portable ultrasound machine with a 7–12-MHz linear probe. A standoff pad is not typically used.

Ultrasound Examination

Palmar/Plantar Weight-Bearing Approach

The technique will be described from proximal to distal, beginning with the ISL and ending with the SSL as it becomes part of the middle scutum. The ISL proximal to the sesamoid bones is triangular in shape with a concave palmar margin, a concave to flat dorsal margin and convex medial and lateral margins. At this level the ISL has a predominately homogenous echo pattern as a result of the uniform connective tissue distribution within the ligament. In most horses the width of the palmar/plantar aspect of the ISL will exceed the width of the contact surface of the ultrasound probe requiring this structure to be imaged from the palmar/plantar medial and lateral aspects of the limb. The dorsal aspect of the ligament must be imaged through the suspensory ligament branches when using the medial and lateral approaches. At the level of the sesamoid bones the uniform or homogenous echo pattern persists. However, the curvature of the fibers along the axial margins of the sesamoid bones requires a specific technique relative to the anatomy to create echogenicity in specific aspects of the ligament. The probe position must change multiple times to image the ISL and create echogenic fibers on midline and then in the medial and lateral aspects of the ligament. The axial surface of the proximal sesamoid bones can have depressions or concavities as a result of normal anatomic variation (Fig. 2). However, injury to this region can involve bone loss on the axial margins of the proximal sesamoid bones and a distinction must be made between anatomic variation and pathologic change. Within the dorsal aspect of the ISL at this level there are typically vessels creating multifocal echolucencies. The ISL should be imaged continuously from its proximal extent distally to the level of the ergot, which is typically at the level of the transition between the ISL and the SSL. At this point in the examination, the best method for imaging the ISL and SSL junction will depend on the conformation of the fetlock and the size of the ergot (Fig. 3). In certain horses the region is best imaged with the probe proximal to the ergot. However, in most horses it is best imaged distal to the ergot. Complete examination of this transition requires beginning with an image that contains solely the base of the proximal sesamoid bones well above the junction between the ISL and the SSL. In the absence of moderate or greater osseous abnormalities, the shape and size of the palmar margins of the prox-
Fig. 1. Longitudinal/sagittal and transverse ultrasound and MR images at the level of the fetlock joint and proximal phalanx demonstrating the normal anatomic features and corresponding echogenicity pattern of the structures in this region. The white boxes on the transverse MR images outline the anatomy on the ultrasound images that were obtained to demonstrate the normal appearance of the SSL and ISL. The white lines in the sagittal MR images denote the level of the transverse images that were obtained from proximal to distal. The white box on the first sagittal image represents how much of the anatomy may not be imaged with ultrasound if precaution is not taken to visualize under the ergot. The arrow denotes the sagittal part or dorsal bundle of the SSL. The relaxation artifact of the SSL can be identified on both sagittal MR images to varying degrees. This artifact can complicate interpretation of the MR images.
mal sesamoid bones should be symmetrical and centered on the image. Once this image is obtained the probe should be slowly fanned distally, and as the sesamoid bones disappear this will denote the junction between the ISL and the SSL, which will be detectable based on changes in the shape of the ligament as well as the echo pattern. At this level the SSL is almost triangular to trapezoid in shape, with a wider palmar aspect when compared with the dorsal aspect. In addition to the characteristic shape, the echo pattern becomes more heterogeneous at this level as a result of a less uniform distribution of connective tissue and a greater variation in the fiber pattern. In addition, the cruciate ligaments will be visible at this level immediately dorsal to the SSL continuing to the level of the joint or proximal aspect of the proximal phalanx, again depending on conformation. At this level the SSL begins to transition from being trapezoid to being triangular in shape. Distal to the cruciate ligaments the dorsal fiber bundle or sagittal part of the SSL typically becomes evident and can have a variety of appearances. It is important to recognize this as a normal anatomic feature and not a region of fiber disruption or separation. It can remain a single bundle of fibers or split into two bundles that separate extending medially and laterally. The dorsal fiber bundle or sagittal part becomes separated from the SSL at the proximal phalanx and traverses toward the oblique sesamoidean ligament (OBSL)s as it continues distally and inserts on the palmar/plantar aspect of the proximal phalanx at the distal extent of the OBSLs and sometimes seems to merge with the axial margins of the OBSLs proximal to the insertion on the middle phalanx. Proximal to the level at which OBSLs are inserting, and typically distal to the palmar or plantar joint recess the SSL changes from being triangular in shape to being oval, typically coinciding with the separation of the dorsal fiber bundle or sagittal part. The fibrocartilaginous region of the distal SSL, given that it merges to become a part of the middle scutum, is variable in size and shape creating a prominent echolucency on midline.

Fig. 2. The undulating margin of the sesamoid bones in this case is normal variation. However, this shape can complicate imaging of the ISL as there is more variation in the fiber pattern and ligament width with this anatomic feature. Additional angles with the ultrasound probe will be necessary to create echogenicity in the ligament given that the echogenicity is less uniform. This should not be confused with bone loss. However, if the distinction is difficult to make then additional imaging can be helpful such as radiographs and nuclear scintigraphy as well as serial ultrasound examinations to look for progression of any bone loss to distinguish pathologic change from anatomic variation.

Fig. 3. The probe placement necessary for imaging the transition between the ISL and SSL can vary based on the fetlock conformation. The region should be imaged with the probe placed both proximal (A) and distal (D) to the ergot identifying the base of the proximal sesamoid bones and then fanning (B and C) the probe distally to identify the junction between the ISL and SSL. In most cases, one of the methods, either proximal or distal to the ergot will produce better images and this method should be used as the primary probe position for evaluation of the palmar soft tissue structures. This region should then be assessed for any abnormalities. This process should be repeated with the limb in nonweight-bearing position to determine whether this yields any additional information.
4. Nonweight-Bearing Technique and Displacement of the Ergot

Techniques, including nonweight-bearing and manual displacement of the ergot, are helpful and in certain cases necessary to fully assess the ISL and the SSL. Placing the limb in a nonweight-bearing position permits displacement of the ergot allowing the ultrasound probe to be positioned in a manner that allows continuous imaging of the ligament. This position may be proximal or distal to the ergot, which is dependent on the conformation of the horse. Each position should be attempted to determine which method yields more information. Alternatively, both methods may be needed to provide the most complete information. Additional advantages of placing the limb in a nonweight-bearing position are a decrease in the curvature of the tendons and ligaments allowing a more uniform probe angle to evaluate the region, sometimes decreasing the technical difficulty, and in certain cases increasing the conspicuity of lesions. In some cases, the decreased stress on the ligamentous structures that occur with the limb in a nonweight-bearing position can increase lesion size allowing better visualization.

5. Appearance of the Pathologic Change

Evaluation of the size, shape, margins, and echo pattern are used to identify injury in tendons and ligaments. When attempting to diagnose injury in a particular structure it is helpful to know the appearance of injuries that occur frequently. This knowledge aids in the recognition of abnormalities in the echo pattern as a result of these injuries. Structures that have a heterogeneous echo pattern as a result of the normal anatomy are the most difficult to evaluate given that subtle lesions can be overlooked with ultrasound due to difficulty of visualization. However, in certain cases sequential ultrasound examinations in conjunction with comparison with the opposite limb can be helpful in differentiating normal anatomic variation from pathologic change.

This is particularly helpful when evaluating the proximal SSL. The more uniform appearance of the ISL and the distal aspect of the SSL makes the detection of abnormalities easier compared with the proximal SSL where the anatomy is most complex (Figs. 4 and 5). Injury of the proximal ISL can be detected by recognizing an abnormal echo pattern, size, shape, or margin. Examination of the proximal ISL is technically challenging because it must be performed in multiple parts. Understanding the anatomic limitations of the ISL at this level is necessary to ensure the entire ligament has been evaluated using the palmar, medial, and lateral approaches. The ISL at the level of the proximal sesamoid bones is evaluated in conjunction with the axial aspect of the proximal sesamoid bone margins and injury in this region can have an osseous and soft-tissue component (Fig. 5). Evaluation of the ISL at the level of the proximal sesamoid bones is technically challenging because the ligament fibers curve along the margins of the proximal sesamoid bones. The probe position must change along this curvature to create echogenicity in the ligament. Similar to the proximal ISL, the ligament has a homogenous echo pattern at this level. Therefore, decreases in echogenicity suggest fiber abnormalities. However, extreme care must be taken to ensure that the decreased echogenicity is real and not the result of the ultrasound beam angle. The probe must be continually moved along the arc of the palmar axial margin of the proximal sesamoid bones to create echogenicity incrementally within the ISL. The injury at the junction of the ISL and SSL that is frequently diagnosed with MRI and could be de-
ected with ultrasound consists of focal circular to oval regions of fiber disruption and/or fiber abnormality that can be identified immediately distal to the sesamoid bones (Fig. 6). The regions of abnormalities are typically located medially or laterally, and more often both the medial and lateral aspects are affected but to differing degrees.

Fig. 5. Injury to the intersesmoidean ligament with adjacent osseous abnormalities (B) of the proximal sesamoid bones is seen as well in the corresponding radiographs (A). Abnormalities are seen in the proximal ISL (arrow) at the level of the suspensory ligament branches (C) as well as at the level of the sesamoid bones.

6. Conclusions

Ultrasound is a useful imaging modality for the diagnosis of injury to the ISL and SSL. MRI will still be required to diagnose certain injuries affecting the ISL and SSL. However, with an understanding of the normal anatomy, anatomical variations, and the

Fig. 6. Corresponding MRI and ultrasound images from three cases with injury to the proximal extent of the SSL at the transition with the ISL compared with normal anatomic reference image at this level. These images demonstrate the typical appearance of injury to the SSL at this level with focal circular to oval regions of fiber disruption and/or fiber abnormalities that can be identified immediately distal to the sesamoid bones. Focal hyperechogenic regions are consistent with fibrosis or mineral that is not dense enough to prevent the ultrasound beam from continuing through the tissues. As demonstrated by these cases, the regions of abnormalities are typically located medially or laterally within the ligament, and both the medial and lateral aspects can be affected, but often to differing degrees. A gross image is provided to demonstrate a normal anatomic representation of the SSL.
knowledge of the techniques necessary to fully evaluate these structures, many clinically relevant injuries to the ISL and SSL can be reliably diagnosed and monitored with ultrasound.

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Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

References and Footnote


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Formation and Prevalence of Radiographic Abnormalities of the Medial Femoral Condyle in Thoroughbred Horses From Six to 20 Months of Age

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Radiographic abnormalities (RAs) of the medial femoral condyle (MFC) occur in 42% of young Thoroughbred horses, and can appear as early as 6 months of age. MFC RAs change appearance in 45% of young Thoroughbreds. MFC lucencies discovered in younger horses were more likely to improve than if discovered later. Authors’ addresses: College of Veterinary Medicine, Kansas State University, Manhattan, KS 66506 (Santschi, Canada); Equine Medical Associates, 996 Nandino Blvd, Lexington KY, 40511 (Prichard, Whitman, Berk, Peterson, Morehead); e-mail: santschi@vet.k-state.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction

During the last 25 years, young Thoroughbred horses (≤ 2 y) have been subjected to increasing radiographic scrutiny of joints critical to performance and frequently affected by radiographic abnormalities (RAs). The first sets of radiographs are typically taken of weanlings before the November sale as either a survey or closer to the sale for inclusion in the radiograph repository. “Survey sets” are taken 3–8 months before sales to detect RAs that may either affect marketing decisions or detect RAs that can be improved with therapy. Another set of radiographs is taken near sale time and are available at the sale as a resource for buyers. A horse sold as weanling, yearling, and 2-year old in training would likely be radiographed at least four times. A benefit of this radiographic scrutiny is the ability to detect RAs in large numbers of horses in the early stages of development and follow the progress over time. Coincident with early radiographic scrutiny of sales horses, has been the development of digital radiography, which provides more consistent and detailed images than previously available. In addition, the standard for stifle radiography has evolved from a lateral to medial projection alone1 to three required projections including a lateral to medial, caudo-cranial elevated 15° proximodistal, and caudo 30° lateral-cranio-medial oblique projections. The latter two projections allow a more thorough evaluation of the medial femoral condyle (MFC).

Subchondral lucencies (SCLs) in the MFC of the horse were first described as bone cysts or osseous cyst-like lesions.2,3 Cysts are usually described as round with a narrow connection with medial femorotibial joint located in the central third of the MFC.
as observed in a caudo-cranial projection. More recent descriptions of MFC RA added flattening and concave lucencies of the central MFC.4-6 Because MFC RAs are most commonly diagnosed in young horses, the cause has been suggested to be osteochondrosis,7,8 however, trauma has also been proposed.9 Gross pathologic examination of large SCL reveals voids containing fluid, fibrous strands, and debris.9 Initial histologic studies revealed fibroplasia and capillary proliferation as well as fibrous tissue, degenerated bone and cartilage, and disorganized areas of granulation tissue and woven bone.9,10 More recent histologic investigation of “true cysts” found fibroblasts and osteoclasts in the margins, and granulation tissue, discontinuous trabeculae, and small fragments of necrotic bone that were interpreted as microfractures. There was a thickened cartilage area superficial to areas of chondronecrosis that demonstrated folding of the cartilage into the area of granulation tissue.4,11 Biochemical analysis of tissue removed arthroscopically from MFC bone cysts reveals that inflammatory cytokines associated with bone resorption are present and likely play a role in SCL formation and lameness.12,13

MFC RAs do not always cause lameness, and follow-up of sales horses with MFC RAs provides contradictory evidence of an effect on performance. In a small number of Thoroughbred sales horses, no effect on race records of MFC RA was found; however, a larger study of Thoroughbreds in Australia detected a negative effect on 2- and 3-year-old race records with cystic lesions deeper than 6 mm.4 An issue more important for breeders is the significance of MFC RA on price (cysts and lucencies) of MFC RAs.5 Underlying the progression of MFC RAs progress may provide strategies to better manage the condition or reduce the occurrence.

Approximately 5% of yearling sales horses (Thoroughbred and Quarter Horse) have MFC bone cysts4,6,14 although the prevalence for all young horses is probably higher due to the exclusion of yearlings with lesions from the sale. Our observation is that if MFC flattening and small lucencies on the axial (in contact with the medial intercondylar eminence) and central surface of the MFCs were included for Thoroughbreds, the prevalence would be closer to the 40% reported for yearling Quarter Horses.6 Our goals for this study were 1) to describe the progression of MFC RA in young horses, 2) to determine the prevalence of MFC RA in Thoroughbred horses less than 1 year of age, and 3) to determine the prevalence of changes in the MFC up to 20 months of age.

2. Materials and Methods

The MFC was examined in stiffe radiographs in three groups of horses. All initial radiographs included three projections: lateral to medial, caudo-craniocentral elevated 15° proximodistal (Ca-Cr), and caudo 20° lateral-cranio-lateral view (Cl-CmO). All subsequent radiographs included at least the Ca-Cr view, and often also the Cl-CmO. Group 1 horses were born in 2013 and 2014 and were selected to improve understanding of the progression of MFC RA. These horses were less than or equal to 1 year of age at first set of radiographs that were obtained as survey sets for regular clients of the practice. There was a severe MFC RA in at least one stiffe joint. The MFC RAs were: MFC articular flattening with greater than 10 mm sclerosis, sclerosis with an irregular lucency at the joint surface of the central MFC, or a large concave lucency in the MFC (Fig. 1). MFC flattening alone (without sclerosis) was not included. There were at least three sets of stiffe radiographs taken at 60-day intervals. At 120 and 240 days, the appearance of both MFCs were summarized as improved, worse, or the same. Improvement was a return of the distal articular surface, a loss of sclerosis, or densification of a lucency. Worsening RA was an increase in the size of sclerosis or lucency. If there was no change in radiographic appearance, the MFC was graded as same.

Group 2 horses were born in 2014 and were less than or equal to 1 year of age at first set of radiographs obtained for clients of the practice (for survey or for inclusion in the sale) or were repository sets read for prospective buyers of weanlings. Grades assigned for each MFC were normal, mild flattening, flat, and lucency (includes rounded and irregular). Normal MFC shape was a smooth and continuously convex contour,6 slight flattening was a minor loss of convexity, flat is an obvious flat spot, and a lucent MFC had a loss of bone density at the articular surface that was either rounded or irregular (Fig. 2).

Group 3 horses were a subset of Group 2 that had stiffe radiographs taken for the 2015 yearling sale radiograph repository and MFC shape and density were graded the same as Group 2. For comparison over time, a summary grade based on the most severe MFC RA (in either stiffe) was assigned to Group 3 horses at both time periods (weanling and yearling age) and were judged as the same, improved, or worsened. The best grade was normal, followed by slight flat, flat, and a concavity or lucency at the articular surface was considered the worst. Horses’ sex and the age at imaging were also recorded.

Age was analyzed using the Student t test and categorical differences were analyzed with χ²-squared analysis. Significance was a P ≤ .05.

3. Results

There were 11 horses in Group 1 that averaged 260 days of age (range, 182–310 d) when the first set of stiffe radiographs were obtained. There were three males and eight females. At set 1, four horses had unilateral MFC RA (three right, one left), and seven were bilateral. The summary grade of the worst lesion was: two horses had large rounded lucencies, six had lucencies and sclerosis, and three had
flattened central articular surfaces with deep sclerosis. All RAs on the Ca-Cr projection were widest at the joint margin (8–12 mm). At 120 days after set 1, four horses showed improvement, five had worsened, and two were the same. In nine horses radiographed at 240 days after the first set, five horses were improved, three had worsened, and one was the same. The four improved horses had substantial healing of lucencies, and three of the four were unilaterally affected. The three horses that worsened had enlargement or development of lucencies (two bilateral, one unilateral), and the same horse had no change in a shallow lucency.

There were 638 horses of an average age of 239 days (range, 124–365 d) in Group 2. There were 287 females (45%) and 351 males (55%). Summaries for Group 2 MFC grades are listed in Table 1. Of the 267 horses with an RA, 106 (39.7%) were affected bilaterally. Of the 162 unilaterally affected horses, 108 (67%) were right MFCs and 54 (33%) were left MFCs. There was no association of horse’s sex with MFC RA. Considering all MFC, there were significantly more abnormal grades in right MFCs (41.8%) than left (24%). There were 188 horses with an average age of 529 days (range, 455–595 d) in Group 3. There

Fig. 1. Caudo-cranial projections of the MFC in Group 1 horses. A, Deep sclerosis of the central MFC, (B) MFC sclerosis with an articular lucency, (C) a large MFC concave lucency. Thin arrows indicate sclerosis, thick arrow indicates the lucency.

Fig. 2. Caudo-cranial stifle joint projections demonstrating the MFC grades for horses age < 1 year.
were 81 females (43%) and 107 males (57%). The MFC grades for Group 3 at both ages are listed in Table 1. Of the 82 horses with an RA, 46 (57.3%) were affected bilaterally. Of 36 unilaterally affected horses, 25 were of the right MFC (69%) and 11 of the left (31%). There was no association of horse’s sex with MFC RA in Group 3. Table 2 provides detail about the changes in MFC grade in Group 3; there was a nonsignificant increase in the prevalence of flattening and a nonsignificant decrease in the prevalence of lucencies with age. Eighty-five percent of horses with normal MFC at set 1 had a normal grade at set 2, whereas only 37% of horses with a lucency had a lucency at set 2, and 63% healed. Horses that healed the lucency between stifle radiograph sets were younger (mean, 219 d) at set 1 than those that retained the lucency (mean, 251 d; P = .03).

4. Discussion
Most reports on RA of the MFC focus on the treatment of bone cysts causing lameness in horses greater than 1 year of age. With the exception of a recent novel technique,15 most treatments either poorly document radiographic healing or report it as uncommon.2,10,16 However, in younger horses, radiographic healing of osteochondral abnormalities in several locations, including the lateral trochlear ridge of the stifle, has been reported up to 8 months of age (the MFC was not examined).17 Our experience with juvenile Thoroughbreds was that improvement in MFC RAs can occur if they arise before 1 year of age and that development of large MFC lucencies “bone cysts” was uncommon after the yearling sale (age range, 16–20 mo). This suggests a window of susceptibility to the development of MFC RA in young Thoroughbred horses. This period is one of dynamic development of the musculoskeletal system that includes rapid bone growth, substantial increases in weight, and increasing exercise. Because MFC RAs arise during skeletal development, osteochondrosis has been considered a potential cause;7,8 however, since the first descriptions, mechanical trauma has also been considered a factor.9

The progression of MFC RAs in this study as indicated in Fig. 3 suggests that in affected horses, the first RA detected is a large (> 100 mm²) area of sclerosis in the proximal trabecular bone and flattening of the MFC. Most frequently, the affected area is the central MFC in contact with the tibial plateau, although it can occur axially. If the RA progresses, a wide lucency appears at the joint surface within the sclerotic area, which gradually enlarges and becomes rounded, (Type 1 subchondral bone cyst [SBC]10). Concurrently, the area of deep sclerosis becomes smaller, but a dense sclerotic margin forms around the lucency including the joint surface. Finally, the communication with the joint and the lucency narrows. This narrowing at the joint is also seen in early healing of horseshoe-shaped lucencies (Type 4) after placement of a transcondylar screw,15 and probably represents an attempt at healing combined with some collapse of the articular margin of the lucency (barreling). Regression (improvement) or healing of MFC RA is demonstrated by a reduction in the size of the deep sclerosis and lucency, and some

### Table 1. Grades of the MFC of Group 2 at a Mean of 239 Days of Age and of Group 3 at a Mean of 239 and 529 Days of Age

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Group 2: age 239 d</th>
<th>Group 3: age 239 d</th>
<th>Group 3: age 529 d</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left, n (%)</td>
<td>Right, n (%)</td>
<td>Either, n (%)</td>
</tr>
<tr>
<td>MFC grade (N = 638)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>478 (75)</td>
<td>425 (66.6)</td>
<td>371 (58.2)</td>
</tr>
<tr>
<td>Mild flattening</td>
<td>90 (14.1)</td>
<td>125 (19.6)</td>
<td>135 (21.2)</td>
</tr>
<tr>
<td>Flat</td>
<td>6 (0.1)</td>
<td>8 (1.3)</td>
<td>11 (1.7)</td>
</tr>
<tr>
<td>Lucency</td>
<td>64 (10)</td>
<td>80 (12.5)</td>
<td>121 (18.9)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Normal</td>
<td>137 (72.9)</td>
<td>117 (62.2)</td>
<td>106 (56.4)</td>
</tr>
<tr>
<td>Mild flattening</td>
<td>31 (16.5)</td>
<td>47 (25)</td>
<td>46 (24.5)</td>
</tr>
<tr>
<td>Flat</td>
<td>0</td>
<td>1 (0.5)</td>
<td>1 (0.5)</td>
</tr>
<tr>
<td>Lucency</td>
<td>20 (10.6)</td>
<td>23 (12.2)</td>
<td>35 (18.6)</td>
</tr>
</tbody>
</table>

### Table 2. Changes in MFC Grade in Group 3 Horses From a Mean of 239 Days of Age to 529 Days of Age and the Mean Age at the First Set of Selected Grading Groups

<table>
<thead>
<tr>
<th>General N = 188</th>
<th>No. of Horses</th>
<th>Mean Age for First Set of Radiographs, d</th>
<th>Age Range, d</th>
</tr>
</thead>
<tbody>
<tr>
<td>No change</td>
<td>103 (54.8%)</td>
<td>243</td>
<td>167–353</td>
</tr>
<tr>
<td>Change</td>
<td>85 (45.2%)</td>
<td>234</td>
<td>124–365</td>
</tr>
<tr>
<td>Improved</td>
<td>44 (23.4%)</td>
<td>231</td>
<td>161–365</td>
</tr>
<tr>
<td>Worse</td>
<td>41 (21.8%)</td>
<td>237</td>
<td>124–363</td>
</tr>
<tr>
<td>Normal (set 1 only)</td>
<td>86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No change</td>
<td>73 (85%)</td>
<td>240</td>
<td>167–353</td>
</tr>
<tr>
<td>Developed lucency</td>
<td>8 (9.3%)</td>
<td>222</td>
<td>191–254</td>
</tr>
<tr>
<td>Developed flattening</td>
<td>5 (5.8%)</td>
<td>286</td>
<td>254–322</td>
</tr>
<tr>
<td>Lucency (set 1 only)</td>
<td>35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No change</td>
<td>13 (37%)</td>
<td>251</td>
<td>195–325</td>
</tr>
<tr>
<td>Healed lucency</td>
<td>22 (63%)</td>
<td>219</td>
<td>161–280</td>
</tr>
<tr>
<td>Lucency (set 2)</td>
<td>188</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Developed lucency</td>
<td>14 (7.4%)</td>
<td>228</td>
<td>183–350</td>
</tr>
</tbody>
</table>
degree of return to the normal trabecular bone pattern. Substantial healing occurred in some horses in this study (Fig. 4); however, a return to normal did not occur.

Bone remodeling is driven by the local mechanics.\textsuperscript{18,19} Frequency and amplitude of external load are contributing factors, but loading rate seems to be the primary stimulation for osteocytes\textsuperscript{20} that act as strain gauges within mineralized tissue.\textsuperscript{21} Osteocytes recruit osteoblasts,\textsuperscript{21} which increase intramembranous bone formation on existing trabeculae, resulting in thickened trabeculae and radiographic sclerosis. However, when loading parameters exceed the failure threshold (occurring at very small strains in trabecular bone\textsuperscript{22}) microcracks form.\textsuperscript{23} Diffuse microcracks are produced during constituent activities\textsuperscript{24,25} and are managed by a balance of the

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**Fig. 3.** Sequential caudo-cranial projections of the MFC in a young Thoroughbred that developed a large rounded lucency.

**Fig. 4.** Examples of healing of medial femoral condylar abnormalities on caudo-cranial projections taken 6 months. Letters indicate the same horse.
activities of the osteoblasts and osteoclasts, but local concentrations of excessive microcracks likely recruit activated osteoclasts causing focal mineral resorption. These focal areas of resorption have a local strain-enhancing effect that could reinforce the activation of osteoclasts, bone removal, and void enlargement. We hypothesize when overload is persistent, remodeling becomes maladaptive, the void reaches a critical size, and the articular cartilage collapses. Cartilage collapse exposes bone to synovial fluid. Bone has been shown to be a primary source and reservoir for inflammatory mediators in osteoarthritis, and is also probably a factor in the formation of large lucencies in the MFC. Up-regulation of inflammatory mediators in the fibrous tissue in equine SCL has been demonstrated, and tissue media from the cyst lining increases osteoclast activity. Inflammation contributes to further bone removal. Eventually, a pathologic steady state is achieved in the MFC and there is little net change in the size of the lucency. However, joint inflammation persists, and in concert with the roughened cartilage surface, can cause further cartilage and meniscal deterioration.

We believe that extensive focal damage to MFC trabecular bone, the subsequent cartilage collapse, and local osteosynovial inflammation is sufficient for the formation of MFC RAs in young horses. It also explains the relatively small amount of articular cartilage damage (as compared with bone) in young horses with large lucencies. However, little is known about the timing of the disappearance of growth cartilage of the articular surface of the MFC and the formation of the subchondral plate, so it is not possible to rule out a contribution from injury to growth cartilage (osteoarthrosis) as a cause for MFC RA as has been postulated.

The prevalence of MFC RA in this study is similar to the 40% (yearlings) or 44% (2 year olds) reported for Quarter Horses. Comparison of Groups 2 and 3 suggest that healing of lucencies is possible in some horses, but that development of new lucencies can also occur. Horses that were younger when a lucency was discovered were more likely to heal, suggesting that early diagnosis might allow implementation of strategies such as restriction of exercise to promote healing. However, we have no information on the exercise allowed subject horses. Besides youth, it was not possible to determine other factors that contributed to healing. Studies are ongoing investigating whether exercise restriction will promote MFC RA healing. The right-sided predilection for MFC RA was first described by our group and similar results have been reported subsequently. The reasons for the asymmetry are unknown, but given that this study reports a right-sided predilection for MFC RAs in untrained horses, trained activity is unlikely to be the cause.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

References


How to Diagnose Subchondral Bone Injury of the Fetlock in Sport Horses Using Field Radiography

Laura Faulkner, VMD*; Christopher Miller, DVM; and Sarah M. Puchalski, DVM, DACVR

1. Introduction
Subchondral bone injuries of the distal third metacarpal (MC III) and third metatarsal (MT III) bones and proximal first phalanx (P1) have long been recognized as common causes of lameness in Thoroughbred and Standardbred racehorses.1–4 However, subchondral injuries in the bones comprising the metacarpophalangeal or metatarsophalangeal (fetlock) joints of sport horses have only been minimally discussed in the literature.4–6 In addition, the literature addressing subchondral bone injuries of the fetlock joint focuses on the use of advanced imaging technology, including nuclear scintigraphy, computed tomography (CT), and magnetic resonance imaging (MRI), to substantiate the diagnosis.4–8 Although advanced imaging may provide valuable information about subchondral bone injuries to the fetlock joint, it is not always readily available or affordable.

The ability to detect subchondral injuries of the fetlock joint using field radiography would be an essential tool for equine ambulatory practitioners. In racehorses, the primary area of interest for subchondral injury of distal MC III or MT III is the palmar or plantar aspect of the condyle and special radiographic projections were developed for evaluation of this region.1,2,4,9

To assist practitioners in achieving the diagnosis of subchondral bone injury of the fetlock joint in sport horses, the objectives of this paper are 1) to review the relevant anatomy and standard radiographic projections of the fetlock, 2) to introduce nonstandard radiographic projections that should be included in routine evaluation of fetlock joint-related lameness in the sport horse, and 3) to present a case series of sport horses diagnosed with injuries of the subchondral bone of the fetlock joint using field radiography.

2. Materials and Methods
Clinical Cases
Twelve horses cared for by Miller & Associates, Brewster, NY, were identified by retrospective review of medical records as being diagnosed with subchondral bone injury of the fetlock joint using field radiography over a 7-year period (2009–2016). The medical records were reviewed and information regarding signalment, clinical examination, diagnostic imaging (radiography, ultrasound, nuclear scintigraphy, MRI, CT), treatment, and follow-up

NOTES
was gathered. All horses had standard and non-standard radiographic projections. Seven horses had other diagnostic imaging studies in addition to radiography.

**Preparation**

Although no special preparation is necessary to acquire radiographic views necessary for identification of subchondral bone defects, routine preparation of the horse for radiography includes removing any dirt or gross debris from the skin surface in the fetlock region. Depending on patient compliance and pain level, sedation may be required to acquire optimal radiographs. For all radiographs of the distal limb, particularly when the evaluation of joint space is anticipated, the horse should be standing squarely, with equal weight on the medial and lateral aspects of the limb. Generator settings and film focal distance are equipment dependent and manufacturer or user protocols should be used. External radiographic markers are strongly recommended to annotate the lateral (or dorsal) aspect of the limb. Many digital radiographic markers are not accurate when acquiring non-standard projections.

Prior to beginning the radiographic examination, it is important to consider the anatomy of the fetlock joint and the common sites of fetlock joint-related pathology. For example, dorsopalmar, dorsoplantar, and oblique projections taken with a flat beam angle will superimpose the proximal sesamoïd bones over not only the MC III or MT III condyle but also over the articular surface, both of which are common sites of pathology. In addition, because of the curving nature of the distal MC III or MT III condyle, a steeper dorsopalmar or dorsoplantar projection will highlight a more dorsal portion of the distal condyle or articular margin than will a flatter beam angle (Fig. 1). In all cases of fetlock joint-related lameness in sport horses, we recommend obtaining both the standard and nonstandard radiographic views described below. However, differential diagnoses in a particular case may warrant obtaining additional views.

**Standard Radiographic Views of the Fetlock Joint**

Although the number of views and radiographic beam angle projections included in a standard fetlock study may vary depending on region and practice, in general five views are taken as standard radiographic projections of the fetlock joint in sport horse practice. These include the following:

- Dorsal 30° proximal-palmarodistal oblique (D30° Pr-PaDiO) view.
- Weight-bearing lateromedial (LM) view.
- Flexed lateromedial (Fl-LM) view.
- Dorsal 20° proximal 45° lateral to palmaromedial oblique (DLMPO) view.
- Dorsal 20° proximal 45° medial to palmarolateral oblique (DMPLO) view.

**D30° Pr-PaDiO and Dorsal 30° Proximal-Plantarodistal Oblique (D30° Pr-PIDo) Views**

Dorsopalmar and dorsoplantar (DP) views are obtained parallel to the sagittal plane of the limb, and
can be obtained with varying degrees of proximal to distal beam angle (Fig. 1). The standard dorsopalmar or dorsoplantar (D30° Pr-PaDiO or D30°Pr-Pl-DiO) view use 30° of down-angle to project the proximal sesamoid bones above the articular margin, allowing a less-impeded evaluation of the distal MC III or MT III condyles and articular margin.

Weight-Bearing LM and Fl-LM Views
Standing LM and Fl-LM views are obtained perpendicular to the sagittal plane of the limb. In some horses, the coffin and fetlock joints have differing sagittal planes due to variation in conformation, and so positioning for lateromedial views of one may not be appropriate for the other. In addition, the person holding the limb in flexed position for the Fl-LM view must take care to hold the limb perpendicular to the radiographic detector and generator. A correctly obtained lateromedial view should completely align the medial and lateral condyle of MC III or MT III. Because of superimposition, lesions in the subchondral bone of the condyle may be difficult to identify, but lesions of the sagittal ridge are readily evident.

Dorsal 20° Proximal 45° Lateral to Palmaromedial Oblique and Dorsal 20° Proximal 45° Medial to Palmarolateral Oblique Views
Dorsal 20° proximal 45° lateral to palmaromedial oblique (DLPMO) and dorsal 20° proximal 45° medial to palmarolateral oblique (DMPLO) views are typically obtained as dorsal 15–20° proximal 45° lateral (or medial) to palmar/plantar distal medial/lateral. This view is slightly less steep (15–20°) than the dorsopalmar D30° Pr-PaDiO view (30°) from proximal to distal. The view is positioned halfway (45°) between a dorsopalmar and a lateromedial view. Proximal to distal beam angulation at 15–20° projects the proximal sesamoid bones sufficiently away from the joint margin. The 45° angulation from dorsal to lateral (or medial) separates the proximal sesamoid bones and MC III or MT III condyles. Therefore, in a DLPMO view, for example, this separation means the lateral sesamoid and lateral MC condyle can be viewed with minimal superimposition (Fig. 2). However, these views may obscure dorsal proximal P1 fragments when such fragments occur in an axial location.

Nonstandard Radiographic Views of the Fetlock Joint
The following views and techniques are uncommonly obtained in radiographic studies of the fetlock joint in sport horse practice. When made consistently, these nonstandard views allow for evaluation of specific regions of the curving subchondral bone surface that are often implicated in fetlock joint-related lameness in the sport horse. Furthermore, contrast arthrography augments the routine projections and allows for evaluation of the cartilage surface.

Additional Dorsal Proximal to Palmaro- (Plantaro-) Distal Views
Due to the curving nature of the MC III or MT III condyle, varying the proximal to distal beam angle changes the region of the joint through which the beam is tangential (Fig. 1). Steep (45–60° proximal to distal) beam angle is tangential to the dorsal portions of the fetlock joint. A flat beam angle is tangential to the most distal portion of the condyle near the transverse ridge. Given that the exact lesion location (subchondral bone lesion or other) is usually not known in advance of obtaining radiographs, multiple dorsopalmar or dorsoplantar views should be obtained with varying proximal to distal angulation—for example, a D20° Pr-PaDiO view, a D30° Pr-PaDiO view, and a D45° Pr-PaDiO view.

Dorsoproximal to Dorsodistal Skyline View
The dorsoproximal to dorsodistal (DPr-DDi) view, or skyline view, aids in the diagnosis of subchondral lesions of distal MC III. This view is obtained by holding the limb in a forward and flexed position, with the plate underneath the flexed fetlock and the radiographic beam oriented in a nearly vertical direction (Fig. 3). The view is difficult to perform in the hindlimb because the abdomen of the horse can be in the way and the horse often resents having the
hindlimb brought forward and flexed at the fetlock. The value of this view is to present the dorsal portion of the articular surface of MC III with minimal superimposition of additional structures.

Contrast Arthrography
Positive contrast arthrography aids in the indirect evaluation of the cartilage within the fetlock joint. Contrast arthrography is not essential to the diagnosis of subchondral bone lesions of the fetlock joint; however, it can provide additional valuable information about communication between the subchondral bone lesion and the fetlock joint, which in turn can direct the treatment plan and prognosis. To perform arthrography, nonionic, sterile, iodinated positive contrast media* diluted 1:1 with sterile saline is injected into the joint in an aseptic manner. A total volume of 12–15 mL should be injected. After injection, flexion and extension of the joint should be performed, to allow for even distribution of the contrast media. Radiographic projections should be obtained immediately and then again after 1–2 minutes. The dorsopalmar or dorsoplantar projection at varying proximal-to-distal beam angles and the skyline projection are useful for further characterization of subchondral bone lesions of the fetlock joint (Fig. 4).

3. Results
The retrospective review of the medical records at Miller & Associates identified 12 horses diagnosed with subchondral bone injury of the fetlock joint from January 2009 to February 2016. Of the 12 horses that were identified, nine horses had subchondral bone injuries to a forelimb fetlock joint, whereas three horses had subchondral bone injuries to a hindlimb fetlock joint. The distribution of lesions was distal medial MC III (four cases), distal lateral MC III (one case), the sagittal groove of proximal P1 in a forelimb (three cases), proximal medial P1 in a forelimb (one case), and the sagittal groove of proximal P1 in a hindlimb (three cases). No lesions of distal MT III were identified.

All horses in this study were used for jumping, with five show jumpers, four show hunters, and three hunter seat equitation horses. There were seven geldings and five mares. All horses were Warmbloods. The horses ranged in age from 6 years old at the time of injury to 14 years old, with a median age of 10.5 years. All horses were lame. The lameness in the affected limb varied from 1 to 4

![Fig. 3. Illustration of positioning to obtain a DPr-DDi skyline view with a corresponding normal radiograph.](image)

![Fig. 4. DPr-DDi skyline contrast arthrography view of a case with a subchondral lesion of medial MC III. A radiolucent line representing soft tissue is present overlying the subchondral lesion. This indicates either cartilage or other reparative soft tissue overlying the defect.](image)
degrees of five (AAEP Lameness Scale, 0–5/5). Clinical signs suggesting the fetlock joint was the source of lameness were present in eight of 12 cases, including resistance to flexion of the fetlock joint (eight cases), effusion of the fetlock joint (seven cases), and palpable bony remodeling of the dorsal aspect of the fetlock joint (three cases). Multiple signs were present in all eight cases that had clinical signs relating to the fetlock joint. Of the six horses that had intra-articular fetlock joint anesthesia performed, all responded positively; two additional cases had lameness localized to the fetlock region with a low four point nerve block (palmar/plantar nerves and palmar MC/plantar metatarsal nerves, anesthetized, proximal to the fetlock joint); four horses were not blocked.

In all 12 cases, the subchondral bone lesion was identifiable on radiographic views. In three of 12 cases, the subchondral lesions were only visible on nonstandard radiographic projections. In an additional five cases, the subchondral bone lesion was best delineated on a nonstandard radiographic view, but was also identified on the standard projections. In four cases, the subchondral bone lesion was readily evident on standard views. The diagnosis was made initially with radiographs in all but two cases (nuclear scintigraphy was used for the initial diagnosis in one case, and nuclear scintigraphy and MRI in the other case).

Lesions of distal medial MC III and distal lateral MC III were best identified using the DPr-DDi skyline radiographic view (Fig. 5). Some of these lesions could also be seen on variable proximal to distal beam angle DP views (D30°–D45° Pr-PaDiO) (Fig. 6). Lesions of the sagittal groove of proximal P1 and the proximal medial P1 lesion were best identified using variable proximal to distal angle DP views (D30°–D45° Pr-PaDiO) (Fig. 7).

In addition to radiographic imaging, eight horses received other imaging of the fetlock joint of interest: nuclear scintigraphy was performed in six cases, MRI was performed in three cases, CT was performed in two cases, and ultrasound of the soft tissues was performed in six cases, with some horses obtaining multiple additional imaging examinations. In all of the scintigraphic, magnetic resonance (MR), and CT imaging, the subchondral bone lesions were readily evident. Cross-sectional imaging (MR and CT) provided a detailed evaluation of the articular surfaces, allowing for earlier detection of lesions (as seen in one horse) and more complete assessment of the joint. Nuclear scintigraphy maps areas of active bone turnover providing a means of assigning significance to clinical and radiographic findings. Sonographic evaluation of the fetlock joint region was employed to rule out soft-tissue injuries to the fetlock joint region in some cases.

Records from 11 of the 12 cases contained sufficient follow-up information to present treatments and outcomes. The twelfth case is only 1.5 months out from diagnosis at the time of submission of this paper. All horses were rested for a duration ranging from 1 to 8 months, with a mean rest period of 4.5 months and median rest period of 4 months. Intra-articular therapy with hyaluronate sodium
and two horses were retired. An additional horse was lame but still in active rehabilitation.

4. Discussion

Standard and nonstandard radiographic projections of the fetlock joint provide a safe, readily available diagnostic test for the identification of subchondral bone injury of that joint. The incidence of subchondral bone injury in sport horses has been reported as rare, with Dyson and Murray\(^5\) describing 12 cases of 2500 over a 5-year period. However, clinical observation would suggest that this injury is a problem of increasing importance. Historically, the diagnosis has relied upon advanced imaging techniques,\(^5\)–\(^8\) and the ability to recognize the problem with routine diagnostics may show subchondral bone injury to be an underdiagnosed problem.

The radiographic diagnosis of the fetlock subchondral bone injury is dependent on the acquisition of an adequate number of appropriately positioned radiographic projections. This ability is further ameliorated by knowledge of the anticipated pathology. In previous studies touting the importance of advanced imaging techniques to diagnose subchondral bone lesions of the fetlock joint, neither the variable proximal to distal beam angle DP views, nor the skyline view were routinely obtained, but in the cases described herein they were the most useful views.\(^5,6,8\) The majority (three of five cases) of distal MC III lesions were dorsally located and better identified on the down-angle DP view vs a standard DP view. In addition, all of the distal MC III lesions were best identified and characterized on the skyline DPr-DDi views. The literature states that both racehorses and sport horses are predisposed to subchondral bone injury of the sagittal groove of proximal P1,\(^6\) and six of seven cases of proximal P1 injury in this study were in the mid-to-dorsal portion of the sagittal groove, consistent with the literature. These lesions were best seen on the variable proximal to distal beam angle DP views (D30°–D45° Pr-PaDiO).

In the cases described herein, forelimb lesions were more common than hindlimb lesions. No hindlimb lesions of distal MT III were recognized in this study. Because the skyline radiograph is difficult to acquire properly in the hindlimb, it is possible that these lesions are not easily identifiable. It is also possible that the greater repetitive concussive experiences in the forelimbs vs the hindlimbs in jumping horses may increase the incidence of subchondral bone injuries to distal MC III. In contrast, lesions of proximal P1 were more evenly distributed between forelimbs and hindlimbs. Lesions of the medial condyle of distal MC III were more prevalent than lesions of the lateral condyle, which is consistent with previous reports in sport horses and racehorses.\(^4,5\)

In the 11 cases with sufficient follow-up information to analyze, the overall outcome was good, with seven horses returning to their previous level of exercise,
competition. This finding is comparable to other studies in sport horses where 75% of horses returned to their previous level of exercise. However, it is important to note that a lengthy rest period was required in some cases prior to a successful return to exercise. Too few cases and too numerous and varied treatment regimes in this study precluded in-depth analysis of the relative merits of different approaches to treatment, but that would be another interesting area of further inquiry.

In conclusion, we present a new radiographic method for evaluating the fetlock joint of sport horses that allows for the diagnosis of subchondral bone injuries in the field. We strongly encourage equine ambulatory practitioners to obtain both standard and nonstandard radiographic views of the fetlock joint as part of the diagnostic process for fetlock joint-related lameness.

Acknowledgments
We wish to thank Beth Mellor for her illustrations of positioning for obtaining fetlock radiographs.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

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Noltrex, Nucleus Regenerative Therapies, Kennesaw, GA 30152.
Harvest, PRP, Harvest Technologies Corp., Lakewood, CO 80215.
Tildren, Ceva, Libourne Cedex, France 33501; or OSPHOS, Dechra, Northwich, United Kingdom CW9.
Regenerative Laser Therapy (RLT) System, Sound, Carlsbad, CA 92008.
Evaluation of Multiple Angles for Radiographic Detection of Flexor Cortical Lysis of the Equine Navicular Bone

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Alternate-angle skyline radiographs improve detection and characterization of flexor cortical lysis in observers of various experience levels, ultimately increasing interpreter confidence when pathologic change is suspected. Authors’ addresses: Department of Clinical Sciences (Johnson, Frisbie), Department of Environmental & Radiological Health Sciences (Barrett), College of Veterinary Medicine & Biomedical Sciences, Equine Orthopaedic Research Center, Colorado State University, Fort Collins, CO 80523; e-mail: myra.barrett@colostate.edu *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Flexor cortical lysis identified radiographically indicates advanced degenerative change and warrants earlier interventional therapies to ultimately improve case outcome. It would be beneficial to improve radiographic detection of flexor surface abnormalities, specifically those more distally located, which may be currently unrecognized.

2. Materials and Methods
Navicular skyline radiographs (n = 36 limbs) at standard and alternate angles were assessed by five observers at four experience levels (n = 20) for the presence and severity of flexor cortical lysis. In addition, observers reported their confidence in these assessments. Responses were compared based on reviewing a standard skyline or multiple projections.

3. Results
The identification of lysis and the assessment of its severity was most similar to that of radiologists when observers of all experience levels were able to view multiple skyline views. On average, observers of all levels of experience became more confident viewing multiple projections. Radiologists more frequently graded severity and their respective confidence in accordance with magnetic resonance imaging when multiple views were available.

4. Discussion
When using multiple views, radiology residents, students and clinicians with experience detected lysis and assessed its severity most similarly to radiologists, in contrast to using only a standard view. Skyline radiographs using a flatter angle of incidence allow the beam to be tangential to the more distal portion of the navicular bone, ultimately improving detection of lesions in this location.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Prevalence and Evolution of Carpal and Fetlock Abnormalities in Thoroughbred Weanling to Yearling Sales Radiographs

Kathryn E. Atwood, DVM*; Deborah L. Spike-Pierce, DVM; Thomas E. Wittum, MS, PhD; and Sarah L. Grigoleit, BS

Radiographic abnormalities in Thoroughbred weanlings cannot predict abnormalities that will occur in yearlings. Most abnormalities improve from weanling to yearling sales age. Authors’ addresses: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070 (Atwood, Spike-Pierce, Grigoleit); Department of Veterinary Preventive Medicine, The Ohio State University, Columbus, OH 43210 (Wittum); e-mail: katwood@roodandriddle.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Radiographic abnormalities in weanling and yearling Thoroughbreds can affect presumed value due to decrease in racing performance. Little research has been conducted to see how Thoroughbred radiographic abnormalities evolve from weanling to yearling age.

2. Materials and Methods
Repository radiographs of 722 Thoroughbreds were evaluated for specific radiographic abnormalities as weanlings and as yearlings. These irregularities included lucencies of the mid-sagittal ridge, fetlock and pastern joints, as well as sesamoiditis, sesamoid trauma, proximal intermediate carpal bone spurring, and distal radiocarpal (RC) bone changes. Each radiographic abnormality was graded and placed in a specific category. Statistical analyses were performed using JMP version 11.0. Multiple pairwise comparisons were accomplished using the Wilcoxon method.

3. Results
Radiographic abnormalities from weanling to yearling significantly changed \( P < .0001 \). Improvements as yearlings included sesamoiditis (55%), sesamoid trauma (85%), mid-sagittal ridge irregularities (72%), fetlock and pastern lucencies (>45%), proximal intermediate carpal spurring (79%), and distal RC changes (30%).

4. Discussion
Radiographic irregularities have been used to determine value and to predict future athleticism. This study shows that the majority of abnormalities improve by yearling sales. Although palmar/plantar sesamoid trauma improved, sesamoiditis was not well correlated in yearlings. Almost 50% of fetlock and pastern lucencies resolved. Only 30% of distal RC bone abnormalities improved. Overall, radiographic abnormalities in weanlings will improve as yearlings.

Research Abstract—for more information, contact the corresponding author
Acknowledgments

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Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.
The Prognostic Value of Early and Late Magnetic Resonance Imaging in the Investigation of Equine Digital Lameness

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Of 22 horses undergoing magnetic resonance imaging (MRI) within 12 weeks of onset of lameness, 64% returned to their previous or higher level of work. When 33 horses were scanned at least 12 weeks after onset of lameness, 33.3% returned to their previous or higher level of work. Authors' addresses: Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences (Koch, Goodrich), Orthopaedic Research Center (Goodrich), Department of Statistics, College of Natural Sciences (Hess), and Department of Environmental & Radiological Health Sciences (Barrett), Colorado State University, Fort Collins, CO 80523; e-mail: barrettdvm@gmail.com. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Interest in the use of magnetic resonance imaging (MRI) in horses arose partly in an effort to more precisely diagnose the cause of foot pain whose severity could not otherwise be explained by radiography, ultrasonography, or nuclear scintigraphy.

2. Materials and Methods
This was a retrospective case series.

3. Results
Twenty-two horses were identified lame for 12 weeks or less before implementation of MRI. Fourteen (64%) returned to a previous or higher level of work or their lameness improved by one grade or more. When lame greater than 12 weeks before undergoing MRI, 11 of 33 horses (33.3%) returned to a previous or higher level of work or their lameness improved by a minimum of one grade.

4. Discussion
In conjunction with other diagnostics and the clinical scenario, MRI can be used to direct individualized treatment and rehabilitation in cases of distal limb lameness. However, MRI is not commonly utilized until other diagnostic and treatment modalities have failed and many clinicians are hesitant to recommend MRI due to a perceived overreaction of the client to a significant expense. Our study suggests, however, that earlier implementation of MRI in equine digital lameness may lead to an improved clinical outcome.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Dr. Goodrich is a shareholder in Advanced Regenerative Therapies. Dr. Barrett is an owner/partner of Inside Information Radiology, LLC.
Magnetic Resonance Imaging Findings of the Proximal Metacarpus in Cutting Horses

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Cutting horses with proximal suspensory disease have significant pathologic change within the proximal suspensory ligament and its enthesis. Accurate diagnostic imaging allows the lame ness clinician to select treatment protocols targeted to each disease process. Authors’ addresses: Gail Holmes Equine Orthopaedic Research Center, Colorado State University, Fort Collins, CO 80523 (Manchon, Barrett, Kawcak); Animal Imaging, Irving TX 75039 (Hersman); e-mail: phil.manchon@scneequine.com.au. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Proximal metacarpal pain is a common cause of lameness in cutting horses. Radiographic and ultrasonographic examinations to diagnose lesions responsible for clinical lameness can provide ambiguous results. Magnetic resonance imaging (MRI) provides the most comprehensive diagnostic imaging evaluation of lesions specific to this discipline.

2. Materials and Methods
Retrospective evaluation of Quarter Horses competing or training for cutting events referred for MRI of the proximal metacarpus between 2009 and 2012 with a 2-year follow-up period. A single board-certified veterinary radiologist graded severity of bone and soft tissue lesions on a scale from 0 (normal) to 3 (severe).

3. Results
Thirty-two horses were evaluated consisting of 20 right and 24 left forelimbs. The most common findings were third metacarpal (MCIII) sclerosis at the proximal suspensory ligament (PSL) origin (42/44), MCIII resorption at the PSL origin (32/44), and PSL dorsal margin fiber irregularity (31/44). Twenty-two of 30 horses successfully returned to competition with a mean convalescent period of 157 ± 38.2 days. Strong correlation exists between suspensory ligament enlargement, dorsal margin fiber irregularity, and the presence of osseous resorption and sclerosis of the palmar cortex of MCIII.

4. Discussion
Proximal metacarpal pain can present as a result of injury to both the PSL and the surrounding bone. The severity of injury does not appear to influence long-term athletic performance with appropriate treatment and rehabilitation.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors declare no conflicts of interest.
Screening for Femoral Trochlea Osteochondrosis With Ultrasonography in Foals (1–166 Days): Validation and Prospective Farm Study

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Ultrasonography is a reliable imaging technique for detecting and monitoring subclinical femoral trochlea osteochondrosis lesions in young foals. Authors’ addresses: Faculté de Médecine Vétérinaire, Université de Montréal, St-Hyacinthe, Québec J2S 2M2, Canada (Martel, Laverty); Fethard Equine Hospital, Fethard, E91 Y6T 8 Ireland (Crowley, Halley); Animal Oncology and Imaging Center, Hünenberg 6331, Switzerland (Olive); Services vétérinaires équins Dr Claude Forget, St-Jérôme, J7Z 5T7, Canada (Forget); e-mail: sheila.laverty@umontreal.ca. *Corresponding author; †presenting author. © 2016 AAEP.

1. Introduction
Femoral trochlea osteochondrosis can be a career-ending lesion. Early detection of subclinical lesions holds the promise to improve outcome as exercise restriction could promote healing. We hypothesize that ultrasonographic screening will allow the detection of early femoral trochlea osteochondrosis.

2. Objectives
The goals were to describe and validate with histology the sonographic features of the femoral trochlea of healthy and osteochondrosis predisposed neonatal foals and to perform screening in a cohort of young foals.

3. Materials and Methods
Ultrasonographic evaluation of the femoral trochlea of a group of osteochondrosis predilected and control neonatal foals (part of another study) was performed and site-matched histologic samples were obtained for validation. An ultrasonographic examination of the femoral trochleae of a cohort of foals (n = 47, age 27–166 d) was performed and radiographs were taken concurrently and at 1 year.

4. Results
The vascular/cartilage canal architecture was detected in the epiphyseal cartilage by ultrasonography and histologic sections. There was an excellent correlation between the ultrasonographic and histologic cartilage thickness and ossification front indentation measurements (P < .0001). All three features decreased with aging. Subclinical osteochondrosis lesions were detected in six foals (age 28–145 d) and exercise was restricted. No radiographic osteochondrosis lesions were detected at 1 year old.
5. Discussion

Ultrasonography permitted discrimination between ossification variations and early osteochondrosis and a better assessment of the depth and width of the lesions than radiography.

Acknowledgments

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Evolution of Stifle Abnormalities in Thoroughbred Weanling to Yearling Sales Radiographs

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The majority of osteochondrosis (OC)/osteochondrosis dissecans (OCD) of the femoropatellar joint resolve from weanling to yearling sales. Most medial femoral condyle (MFC) lucencies improve but do not resolve by yearling sales. Authors’ addresses: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070 (Spike-Pierce, Atwood, Grigoleit); Department of Veterinary Preventive Medicine, The Ohio State University, Columbus, OH 43210 (Wittum); e-mail: dspike@roodandriddle.com *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Radiographic abnormalities of the stifle can affect presumed value due to decrease in racing performance. There is little data on how stifle radiographic abnormalities evolve in Thoroughbreds from weanling to yearlings.

2. Materials and Methods
Repository radiographs of 1444 Thoroughbred stifles were evaluated for femoropatellar osteochondrosis (OC)/osteochondrosis dissecans (OCD) and medial femoral condyle (MFC) changes of weanlings and yearlings. Each radiographic abnormality was evaluated and placed in a category based on size and appearance. Median change in category was compared between foals based on category at weanling and yearlings.

3. Results
Radiographic abnormalities from weanling to yearling changed significantly ($P < .001$). Femoropatellar OC/OCD resolved in 80% of yearlings. Changes of the MFC improved by one or more categories in 64% of yearlings.

4. Discussion
A study of yearling MFC change has shown no effect on performance but a decrease in purchase price. Surgically debrided femoropatellar OCDs $> 4$ cm and MFC cysts $> 1.5$ cm demonstrate decreased performance. This study shows that the majority of femoropatellar OC/OCD resolves by yearling sales and should not significantly affect weanling value. Many MFC lucencies improve one or more categories by yearling sales but with sclerosis present are less likely to resolve. Overall, radiographic abnormalities of the stifle improve but caution should be taken when evaluating weanling MFC sclerosis.

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Radiographs were read in Keeneland Association’s and Fasig Tipton’s repositories, both in Lexington, KY.
Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Authors declare no conflicts of interest.
Functional Properties of the Equine Digital Cushion in Quarter Horses

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The structural composition of regions of the digital cushion varies. Such structural variations are correlated with the manner in which the digital cushion functions to absorb impact forces. Authors’ addresses: College of Veterinary Medicine (Faramarzi, Khamas), and Graduate College of Biomedical Science (Lantz), Western University of Health Sciences, Pomona CA 91766-1854; e-mail: bfaramarzi@westernu.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Digital cushion (DC) has a more complicated structure contributing to its role in protecting internal structures than previously thought. However, the histological and functional properties of different regions of the equine DC have not been fully studied. Our objective was to examine the regional distribution of connective, nervous, and adipose tissues, and vascular components of the DC in clinically sound hooves of Quarter Horses.

2. Materials and Methods
The DC samples from the axial-proximal, axial-distal, abaxial-lateral, and abaxial-medial regions of 24 Quarter Horse cadaver forehooves were collected, processed, and stained with H&E, trichrome, and elastic stains. On each slide, a 3 × 3-mm area was assessed by light microscopy. Statistical differences investigated using Kruskal-Wallis and Mann-Whitney U tests with \( P < .05 \) and \( P < .008 \) considered significant.

3. Results
The axial-distal region was characterized by the presence of significantly higher collagen \( (P < .0001) \) and lower elastic fibers \( (P < .0001) \) than axial-proximal and abaxial regions. Almost four times as many nerve bundles were present in the axial-proximal region as compared to the axial-distal region.

4. Discussion
The regional structural differences of the DC are presumably associated with different functional properties of those regions. Inability of the DC to protect sensitive internal structures, such as the navicular bone and related structures, when excessive/repeated forces are applied, may initiate pathological changes.

Acknowledgments
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ning, and Danielle Demel for assistance with data collection.

All horses were humanely euthanized for reasons unrelated to this study. This study was approved by the Institutional Animal Care and Use Committee (IACUC).

**Declaration of Ethics**
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**
The Authors declare no conflicts of interest.
Medical Conditions in the Growing Foal

Nathan M. Slovis, DVM, DACVIM, CHT

Medical conditions in the growing foal (>2 wk of age) are vast. The audience will be introduced to the diagnosis and treatment of both bacterial pneumonia and hyperreactive airway disease in the growing foal as well as *Lawsonia intracellularis*, a unique gastrointestinal illness noted in the older weanling. This session will also discuss how to educate your clients on biosecurity issues on the farm when performing yearly vaccinations. Author’s address: Hagyard Equine Medical Institute, 4250 Iron Works Pike, Lexington, KY 40511; e-mail: nslovis@hagyard.com. © 2016 AAEP.

1. Introduction
Respiratory disease in foals is one of the major causes for morbidity and mortality in the young horse. Early detection and treatment of respiratory problems is essential for not only the animal’s wellbeing, but also for future athleticism in performance animals. Disorders of the respiratory system are second in importance only to those of the musculoskeletal system in limiting the athletic performance of the horse.

2. Materials and Methods
Diagnostic approach to respiratory disorders include the following:

- **History**
  - Are other foals affected? If so, how many?
  - Obtain information if there is high morbidity or mortality
  - Viral infections tend to have a higher morbidity compared with bacterial infections
  - Has the foal been treated for pneumonia before and afebrile?
  - If yes, then there may be residual inflammation that may require bronchodilators and corticosteroids either systemically or nebulized.
- **Age and breed**
- **Environment**—Assess the stalls/barn ventilation. Foals that have recovered from pneumonia may still have a persistent cough due to exposure to allergens in the environment.
- **Physical examination**
  - Auscultation of the chest
  - Percussion of the chest
  - Endoscopy—Endoscopic examination allows direct visualization of the upper respiratory tract, guttural pouches, trachea, and mainstem bronchi.
  - Ultrasonography
  - Radiography
  - Transtracheal wash (TTW)

Age and Breed
Knowing the age of the foal will provide insight as to the problem. Congential problems are usually noted at birth whereas acquired diseases such as bacterial pneumonia tend to occur in older foals (>2 wk of age).

The breed of the animal is important in determining the cause of the respiratory disorder. For ex-
ample, Arabian horses with chronic lung infections should be evaluated for combined immunodeficiency syndrome. Selective immunoglobulin M (IgM) deficiency tends to occur more frequently in Arabians and Quarter horses, whereas agamaglobulinemia has been documented in Thoroughbreds and Standardbreds.

Auscultation of Chest

Auscultation of the chest includes the use of either a rebreathing bag or covering the nares to cause hyperpnea. Bronchovesicular sounds in the young animal can be easily heard because of the decreased muscle mass and less attenuation of the lung sounds. Increased airflow will also increase the bronchovesicular sounds especially in febrile, excited, or hyperpneic animals. Auscultatory findings do not always correlate with the degree of alveolar ventilation. Foals with lung consolidation may still have normal bronchovesicular sounds because of the radiation of airflow from the adjacent areas. Therefore, auscultation alone cannot be used to diagnose pathologic condition of the lower airway.

Crackles may be auscultated and represent the equalization of pressure between two compartments (alveoli and the bronchioles) after the airways have opened (mucus in the airway that does not allow air to flow into the alveoli, but when a deep breath is taken, the air movement flows past the mucus and into the alveoli). Wheezes are musical sounds that arise from vibrations within the airway walls by turbulent airflow noted during constriction of the airways.

Thoracic Ultrasound

Ultrasonographic examinations can be performed with a multi-frequency 5.0- or 7.5 MHz linear transrectal transducer (Figs. 1 and 2). The 7.5 MHz displays a depth of 4–12 cm, which is ideal for thoracic examination of a foal. Isopropyl alcohol is copiously applied to the hair coat to provide surface contact between the transducer and the foal. The alcohol helps reduce the intervening trapped air. The thorax should be thoroughly scanned in a dorsal to ventral plane from the 16th to the 3rd intercostal space.

Sound waves are completely reflected at the normal aerated lung interface allowing only the pleural surface to be evaluated. The normal visceral pleural edge of the lung appears as a straight hyperechoic line with characteristic equidistant reverberation air artifacts indicating normal aeration of the pulmonary periphery. The pleural edge of the lung is imaged gliding dorsally and ventrally when watching the patient breath during thoracic ultrasonography. Only when fluid or cellular accumulation in the lung occurs immediately beneath the visceral pleural surface will an acoustic window be created, allowing visualization of pulmonary pathology. The affected area of the lung is hypoechoic and/or lacks the normal air echo at the surface. It is critical to examine the lung carefully during exhalation and inhalation because lesions can move beneath an adjacent rib or inhaled air into the alveoli and surrounding airways will cause reflection of the sound waves, thereby preventing the visualization of pulmonary disease.

Pulmonary abscesses are variable in size and are located anywhere in the lung. Abscesses are identified ultrasonographically in the lung by their cavitated appearance and the absence of any normal pulmonary structures detected within the abscess. The center may appear hypoechoic, isoechoic, or septate, depending upon the type of fluid present.

Pulmonary consolidation is hypoechoic and/or lacks the normal air echo at the surface. Ultrasonographic visualization of consolidated lung occurs because of the replacement of alveolar air with fluid or cells producing an acoustic window.
3. Radiography

Radiography is considered by some to be the principal imaging technique for the evaluation of the thorax. However, radiographic examination has its limits (in the field and patient size); therefore, ultrasonography will be a valuable alternative. Interpretation of radiographs of the lungs and thorax of the horse require fundamental knowledge of the anatomy of the equine lung. In normal lungs, clear margins of the aorta and structures at the base of the heart including the termination of the trachea and the origin of major bronchi should be seen in the dorsal cranial projection. The pulmonary arteries to the right and left dorsal caudal lung segments are seen as they emerge from the base of the heart, ventral and slightly caudal to the tracheal bifurcation. In the ventral caudal projection, smaller branches are seen originating from the pulmonary arteries at the caudal margin of the heart and entering the darker background of pulmonary parenchyma or as summation opacities over the cranial part of the caudal vena cava (CVC) and the caudal part of the cardiac margin. Bacterial pneumonia may begin as a diffuse interstitial disease and, depending on the organism, develop pulmonary abscesses as occurs with Rhodococcus sp. There are diffuse nodular opacities throughout the lung with Rhodococcus equi pneumonia (Fig. 3). Opacification and loss of detail are greatest around the hilus, which may be evidence of lymphadenopathy.

Transtracheal Wash

A transtracheal wash (TTW) is a technique used to collect fluid from the lower respiratory tract for bacterial culture and cytologic evaluation. The results of the wash can help determine a proper management of equine respiratory tract disease. Two techniques to obtain a TTW include percutaneous and guarded endoscopic sampling.

Common Causes of Respiratory Disease in Older Foals

Bacterial Pneumonia

Pneumonia is the leading cause of morbidity and mortality in foals. The etiology of foal pneumonia is complex because of the large number of factors that foals are exposed to which can set the animal up for a bacterial pneumonia. The majority of older foals develop bacterial pneumonia following a viral infection (EHV4). Viral agents damage epithelial cells in the respiratory tree resulting in desquamation and focal erosion of the respiratory epithelium, interruption of the protective mucociliary blanket, and impairment of clearance mechanisms. Parasites can also predispose to bacterial pneumonia by causing immunosuppression secondary to unthriftness or direct inflammation due to pulmonary migration of ascarids.

Clinical Signs

Clinical signs vary considerably with some foals having high respiratory rates, whereas others may have an occasional cough. Coughing, whether intermittent or paroxysmal, is an important early indicator for respiratory disease. Respiratory rates greater than 30 breaths per minute warrant further diagnostic evaluation, which should include auscultation of the chest to assess whether inspiratory or
expiratory crackles or wheezes are noted. Most severely affected foals will have flared nostrils and an abdominal component to breathing with minimal thoracic excursion. Bilateral discharge from profuse to scant and fevers are common findings in foals.

Diagnosis

Auscultation of the chest with and without a rebreathing bag is needed for assessment of bronchovesicular sounds relating to alveolar ventilation. Adventitious lung sounds are considered abnormal and are described as either crackles or wheezes.

Percussion of the thorax consists of tapping the intercostal spaces of the thorax using a large spoon and a neurological hammer while evaluating the sound produced. Aerated tissues produce a resonant sound whereas consolidated lung, lung abscesses, and bowel will produce a dull sound. Once the entire lung field has been percussed, it is compared with that of a normal foal’s lung field.

Ultrasonography and radiography can help identify and characterize pathologic lesions. Culture and cytological evaluation via a TTW can be performed to help determine the etiological bacteria involved.

Treatment

The selection of an antimicrobial regimen is based on the following:

- Identifying the causative agents
  - Common Gram (+) agents include *Rhodococcus equi*, *Streptococcus zooepidemicus*
  - Common Gram (–) agents include *Actinobacillus equuli* and *Pasteurella sp.*
  - Uncommon: Fungal. Foals with diarrhea are more at risk
- Determining the susceptibility patterns
- Host factors
- Tissue distribution of the drug

Foals with pneumonia secondary to severe septicemia require broad-spectrum therapy. Older foals with uncomplicated pneumonia can be initially treated with a Gram-positive regime with the understanding that if a poor response is noted then the institution of broad-spectrum therapy will be necessary.

Anti-inflammatory medications are commonly used in foal pneumonia to help control fever and potentially reduce inflammation of the lower respiratory tract. Foal pneumonia can also benefit from treatment with bronchodilators (see Juvenile Hyperactive Airway Disease section). It is very important to keep dust levels to a minimum in the foal’s environment. This includes soaking all hay given to the mare and foal for 14 days and removing the foal from the stall when it is being cleaned.

Pleural drainage may be warranted when the removal of exudate and debris from the pleural space allows for the re-expansion of the lung. Decisions regarding pleural drainage are based on classification of the pleural fluid as a complicated or uncomplicated effusion. Uncomplicated effusions are those that do not have sufficient volume to cause respiratory distress and are classified as a transudate, which contain less than 10,000 nucleated cells per microliter and less than 2.5 g/dL of protein. Nondegenerative neutrophils are the primary cells seen and mononuclear cells (macrophages, lymphocytes) are the second most common cell type. Complicated effusions are characterized as having a sufficient volume to cause respiratory distress, increased numbers of degenerative neutrophils, putrid odor, cytologically visible bacteria, or positive culture results. Most complicated effusions require pleural drainage.

*Rhodococcus equi*

Pneumonia in foals, caused by *Rhodococcus equi* (*R. equi*) is a well-known worldwide problem. Other less common clinical manifestations of *R. equi* infections in foals include ulcerative enterocolitis, colonic/mesenteric lymphadenopathy, immune mediated synovitis and uveitis, osteomyelitis, pyogranulomatous dermatitis, brain abscess, immune mediated anemia, and septic arthritis. Inhalation
of contaminated dust particles is thought to be an important route for pneumatic infection of foals. Ingestion of the organisms is a significant route of exposure and immunization, but may not lead to hematogenous pneumonia unless the foal has multiple exposures to very large number of bacteria. Epidemiologic evidence suggests that foals that develop *R. equi* pneumonia are most commonly infected during the first few days of life, but clinical signs do not develop until foals are 30–60 days of age or older.\(^4\)

Pathogenesis

*R. equi* is a facultative intracellular pathogen and its infectivity is limited to cells of the monocyte-macrophage lineage. The virulence mechanisms of *R. equi* are associated with the virulence plasmid. These 80–90-kb plasmids encoding a family of seven closely related virulence-associated proteins designated VapA and VapC to VapH, are responsible for the ability of *R. equi* to persist in, and eventually destroy alveolar macrophages. Plasmid-cured derivatives of virulent *R. equi* strains lose their ability to replicate and survive in macrophages and fail to induce pneumonia in foals, confirming the importance of these plasmids for the virulence of *R. equi*.\(^5\)

Foal pneumonia caused by *R. equi* is endemic on some farms, intermittent on others, and absent on most farms. Anecdotally, some mares have reportedly had multiple affected foals, whereas foals of other mares from the same environment are consistently unaffected. The source of infection for foals remains unknown. Results of a previous study suggest that the feces of mares is a potential source of *R. equi* for the environment and possibly a direct source of infection for foals.\(^6\) A study looking at 171 mares in central Kentucky looked at the association between *R. equi* pneumonia status of the foal and shedding of virulent *R. equi* by its dam.\(^6\) Shedding of virulent *R. equi* was observed in at least one sampling period for every mare examined, and >33% were culture positive during all sampling periods. However, significant differences were not observed in either the fecal concentrations of total or virulent *R. equi* from dams of affected foals compared with dams of unaffected foals. The study concluded that dams of affected foals do not shed more *R. equi* in feces than do dams of unaffected foals, suggesting that heavier shedding by particular mares does not explain infection in their foals. However, the finding that virulent *R. equi* in the feces of all sampled mares during at least one sampling period suggests that mares are likely an important source of *R. equi* for their surrounding environment.

The association between the exposure to airborne virulent *R. equi* and the incidence of *R. equi* pneumonia among individual foals was recently assessed.\(^4\) In that study it was noted that airborne concentrations of virulent *R. equi* were significantly higher in stalls than in paddocks and virulent *R. equi* were more frequently isolated from air samples obtained from stalls than from paddocks. Among the foals that later developed *R. equi* pneumonia, it was more likely that virulent airborne *R. equi* was present in the stalls at approximately 1 week of age than for foals that remained free of this disease. These findings suggest that environments containing airborne virulent *R. equi* during the first week of life may influence the risk of subsequent disease of the foal.\(^4\)

Diagnosis

The insidious course of infection makes early diagnosis difficult. Recognition of foals with *R. equi* pneumonia prior to the development of clinical signs would likely reduce losses and limit costs associated with long-term treatment of affected foals. Many diagnostic tests including complete blood cell count, fibrinogen level, thoracic ultrasound, radiographs, and serology have all been used to help distinguish *R. equi* pneumonia from that caused by other pathogens. However, bacteriologic culture or PCR amplification combined with cytological examination of a TTW are still the gold standards used to arrive at a definitive diagnosis.

Foals with a white blood cell count greater than 14,000 cells/μL, with no clinical signs of disease and normal lung sounds should be considered for additional diagnostic tests such as thoracic ultrasonography.\(^7\) Ultrasonography may reveal abnormalities of the peripheral pulmonary parenchyma. If these abnormalities are detected, a TTW and/or antibiotic treatment should be initiated. Farms with endemic *R. equi* that have suffered significant morbidity and/or mortality rates should be monitoring rectal temperatures twice daily, with febrile foals selected for further testing (thoracic ultrasonography) or treatment. In the author’s experience performing twice-monthly thoracic ultrasonography (starting at 3–4 wk of age until 3 mo of age) has proven to be very effective for early disease recognition and reduction of mortality attributed to *R. equi* pneumonia on several endemic farms.\(^3\) Diagnostic thoracic ultrasonography has been shown to be an accurate alternative imaging modality for detection of pulmonary pathology attributed to *R. equi* pneumonia in foals when thoracic radiography is not available. Pulmonary lesions were assigned a grade according to the severity (Table 1). The grading scale ranged from 0 (normal) to 10 (the entire lung surface is affected). A grading scale was implemented to aid in the documentation of lesions to determine whether treatment was successful, and to help with the description of pneumonia. The foal’s grade was determined not by the total number of lesions that were visualized but by the highest grade visualized. For example, a foal with multiple one’s of the left hemithorax as well as one grade 3 would be identified as a grade 3 in the left thorax. The rationale for this early screening is the belief that earlier initiation of specific treatment

\(^1\) Reference omitted.
\(^2\) Reference omitted.
\(^3\) Reference omitted.
\(^4\) Reference omitted.
\(^5\) Reference omitted.
\(^6\) Reference omitted.
\(^7\) Reference omitted.
A dose of 7.5 mg/kg by mouth every 12 hours can keep some promise for the use in *R. equi* against with rifampin because of their synergistic properties. Clarithromycin are commonly used in combination to achieve high tissue as well an intracellular concentration greater than 4 mL in a single site. Practitioners have also administered flunixin meglumine at a dose 1 mg/kg IV before the administration of ganimethromycin to help alleviate any pain associated with the administration of this medication. Pharmacokinetic data of doxycycline in 4–8-week-old foals have shown that oral administration at a dosage of 10 mg/kg every 12 hours would maintain serum, pulmonary epithelial lining fluid, and BAL cell activity above the MIC of *R. equi*. Therefore, doxycycline or minocycline (4 mg/kg orally every 12 h) may be an option for foals that have adverse reactions to the macrolides. The author has used gentamicin (6 mg/kg IV once a day) in some cases of *R. equi* that do not respond to conventional therapy, usually along with a combination of a macrolide and rifampin.

It is very important to obtain a proper diagnosis and culture sensitivity when confronted with pneumonia that has been presumptively diagnosed with *R. equi*. If the patient does not improve with conventional therapy then further diagnostics (TTW) should be explored because resistant *R. equi* has recently been documented.

In a study documenting the prevalence of *R. equi* isolates resistant to macrolides or rifampin and outcome of infected foals, the overall prevalence of resistant isolates in Texas and Florida was 4% (12 of 328 isolates submitted). The survival proportion of foals infected with resistant *R. equi* isolates (2 of 8; 25%) was significantly (*P* = .004) lower than that of foals receiving the same treatment from which susceptible isolates were cultured (55 of 79; 70%). These results underscore the importance of culture and susceptibility testing in foals with pneumonia caused by *R. equi*.

The overall prognosis for successful outcome (survival) has been reported to be approximately 80%. Foals that recover from *R. equi* pneumonia and make it to the racetrack have been shown to perform as well as expected.

### Juvenile Hyperreactive Airway Disease

**Juvenile Hyperreactive Airway Disease**

Juvenile hyperreactive airway disease tends to affect foals 4–7 months of age and is poorly understood. Juvenile hyperreactive airway disease is a syndrome of small-airway disease that has minimal response to antibiotics alone. The majority of the cases in the United States present between June and September.

#### Clinical Signs

Clinical signs are consistent. Foals present with a history of tachypnea with an exaggerated abdominal component, tracheal rattle, and flared nostrils with

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**Table 1. Ultrasonographic Grading of Pneumonia**

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No evidence of pulmonary consolidation. Pleural irregularities that appear as vertical hyperechoic lines and are described as reverberation artifacts. (Fig. 4)</td>
</tr>
<tr>
<td>1</td>
<td>Less than 1 cm in diameter/depth (Fig. 5)</td>
</tr>
<tr>
<td>2</td>
<td>Lesions that are 1.0–2.0 cm in size</td>
</tr>
<tr>
<td>3</td>
<td>2.0–3.0 cm in size (Fig. 6)</td>
</tr>
<tr>
<td>4</td>
<td>3.0–4.0 cm in size (Fig. 7)</td>
</tr>
<tr>
<td>5</td>
<td>4.0–5.0 cm in size</td>
</tr>
<tr>
<td>6</td>
<td>5.0–6.0 cm in size (Fig. 8)</td>
</tr>
<tr>
<td>7</td>
<td>6.0–7.0 cm in size</td>
</tr>
<tr>
<td>8</td>
<td>7.0–9.0 cm in size. If pleural effusion is present then the lesion is assigned this grade regardless of whether you have lesser grades of consolidation or abscessation.</td>
</tr>
<tr>
<td>9</td>
<td>9.0–11 cm in size</td>
</tr>
<tr>
<td>10</td>
<td>The entire lung lobe is affected</td>
</tr>
</tbody>
</table>

Table 1. Ultrasonographic Grading of Pneumonia
Bronchodilator Therapy

Bronchodilators are used to relieve the obstruction of the small airways caused by airway smooth muscle contraction. The administration of bronchodilators should always be combined with strict environmental dust control that includes soaking hay and environmental control measures to reduce the exposure of the foal to airborne particles. The pathogenesis of inflammatory airway disease encountered in horse stables has been implicated in the development of airway obstruction these drugs have poor pulmonary distribution.

Treating inhalant exposure to airborne irritants commonly encountered in horse stables has been implicated in the pathogenesis of inflammatory airway disease. Two main approaches can help reduce exposure of the horse’s airways to respirable particles. The first approach is to use feedstuff and bedding that generate low dust and endotoxin concentration (paper and hemp). The second approach is to increase removal of airborne particles and noxious gases by improving ventilation in the building.

Bronchodilator Therapy

- Clenbuterol (0.8–3.2 µg/kg by mouth BID) is an excellent bronchodilator with mucokinetic properties to help clear mucus from the airways.
- Aminophylline (5–10 mg/kg diluted in fluids can be given BID to QID IV) is a xanthine derivative that is a bronchodilator, enhances mucociliary clearance, increases contractility of the diaphragm, and delays fatigue of the muscles responsible for respiration.
- Glycopyrrolate is used as a rescue drug when immediate bronchodilation is needed. Glycopyrrolate is a synthetic antimuscarinic agent that blocks the M3-muscarinic receptors and causes bronchodilation (0.002–0.007 mg/kg IV SID).
- Inhalation bronchodilators: during severe airway obstruction these drugs have poor pulmonary distribution.
- Albuterol is a beta2 agonist that serves as a rescue therapy. This medication can improve pulmonary function by 70% within 5 minutes of administration. Unfortunately, the effect only lasts 1–3 hours.
- Give 3–6 activations (450 mcg) BID via a metered dose inhaler.

Corticosteroid Therapy

Systemic dexamethasone has been demonstrated to improve lung function within hours of administration with a maximal response obtained by day 7. Steroids not only reduce inflammation within the chest, but over time can up-regulate the number of beta2 receptors within the airways. Dexamethasone is administered intravenously (0.1 mg/kg) once daily and then for another 4–5 days (0.05 mg/kg) after clinical signs resolve. Inhaled steroid therapy can also be used in conjunction of systemic steroids.

Inhaled steroids may be administered for several weeks after the systemic steroid therapy has been discontinued. Examples of inhaled steroids in foals include the following:

- Fluticasone (220 mcg/activation), give 4–8 activations SID for 2 weeks and then every other day for another 2 weeks
- Beclomethasone dipropionate (80 mcg/activation), give 5–8 activations SID for 2 weeks and then every other day for another 2 weeks

Prevention

Inhalant exposure to airborne irritants commonly encountered in horse stables has been implicated in the pathogenesis of inflammatory airway disease. Two main approaches can help reduce exposure of the horse’s airways to respirable particles. The first approach is to use feedstuff and bedding that generate low dust and endotoxin concentration (paper and hemp). The second approach is to increase removal of airborne particles and noxious gases by improving ventilation in the building.

Lawsonia intracellularis

Introduction

Lawsonia intracellularis (L. intracellularis) is an obligate, intracellular, Gram-negative bacterium that is associated with proliferative enteropathy in a variety of species. An economically devastating disease of commercial pig production worldwide, L. intracellularis has been shown to have a detrimental effect on average daily gain and market weight in pigs.13,14 L. intracellularis is also the etiologic agent for equine proliferative enteropathy (EPE), recognized as an emerging pathogen that has been reported worldwide. EPE typically affects young horses, with those between 4 and 9 months particularly susceptible to disease.15–17 The pathogenesis of EPE involves an initial colonization of the mitotically active enterocytes of the crypts resulting in crypt hyperplasia. This hyperplasia leads to ad-
enomatous thickening of the mucosa (commonly noted in the ileum), with later involvement of other intestinal segments possible. In horses, EPE results in hypoproteinemia and hypoalbuminemia, with some horses ultimately dying from the disease despite aggressive care.

Epidemiology

The epidemiology of *L. intracellularis* in the horse remains poorly understood although it is believed that transmission occurs through the ingestion of fecal material from wild or domestic animals. Due to the significant effect of *L. intracellularis* on the swine industry, progress in understanding porcine (PPE) epidemiology is much more evolved than it is with EPE. It has been hypothesized that PPE persists and is transmitted within swine operations via poor/inadequate disinfection techniques as well as subclinical shedders of the bacterium. Indeed, work has shown that subclinically infected pigs can efficiently spread the bacterium among cohorts. Although a study with bi-monthly fecal PCR testing did identify several weanling horses that shed the bacterium in the absence of clinical signs, the role of subclinically infected horses play in transmission remains to be determined. In one study, clinically affected horses were shown to potentially play a role in the transmission of *L. intracellularis*. It is currently recommended that horses with documented EPE not be allowed to comingle with the rest of the herd until after at least 1 week of antimicrobial therapy.

Exposure to *L. intracellularis* is widespread, with reports of EPE cases occurring worldwide. In the United States, regional exposure varies greatly, with farm-specific seroprevalence ranging from 14 to 100%. Interestingly, only 11% of exposed young horses will develop a form of EPE (5% clinical EPE and 6% subclinical EPE). The most commonly affected age groups are weanling and young yearlings, with those between 4 and 9 months seeming to be most suscetible to infection. On occasion, EPE has been diagnosed in older horses up to 17 years of age at the author’s clinic. These older horses typically have an additional underlying disease process (unpublished data). In North America, the disease is often detected between August and January, although cases outside of this timeframe have been reported.

It was once hypothesized that exposure to pig feces is a potential source of infection for horses. However, in most cases of EPE, no history or evidence of exposure to pigs or pig feces has been reported. Molecular typing of equine isolates using variable number tandem repeat has demonstrated a clear distinction between the isolates obtained from porcine and equine species. Rabbits may represent an effective reservoir/amplifier host due to their large population, close contact with horses, their short reproductive cycle, and their worldwide distribution. Recent work has examined a possible role of rabbits in the epidemiology of EPE.

Clinical Signs

EPE is generally seen in weaned horses less than one year of age. Clinical signs are usually nonspecific and include lethargy, pyrexia (*> 38.5°C*), anorexia, peripheral edema (Fig. 9), weight loss (Fig. 10), colic, and diarrhea. Due to the nonspecific nature of the clinical signs, diagnostic testing may be necessary to rule out protein loss in the urine as well as peritoneal and pleural cavities. For those horses that recover, the recovery period can take weeks to months before they regain the appearance of unaffected cohorts.

Diagnostic Tests

Although the definitive diagnosis of EPE requires direct observation of *L. intracellularis* within enterocytes of the hyperplastic small intestine at nec-
ropsy, a presumptive, antemortem diagnosis can generally be made based on age of the affected animal and clinical signs, the presence of hypoproteinemia/hypoalbuminemia, thickened small intestinal loops on abdominal ultrasound, and positive commercially available diagnostic tests for *L. intracellularis*.

Abdominal Ultrasonography

Proliferative enteropathy caused by *L. intracellularis* results in small intestinal mucosal hyperplasia. The use of a 2.5–5.0-MHz ultrasonographic probe is preferred to obtain a depth of 8–20 cm. Although a linear rectal probe may provide sufficient depth to detect thickened small intestine, a negative result using such a probe should not rule out EPE. By itself, small intestinal wall thickness greater than 3 mm is not pathognomonic for EPE, but increased thickness (Fig. 11) accompanied by compatible clinical and clinicopathologic signs is highly suspicious. Practitioners should avoid relying solely on abdominal ultrasonography for EPE diagnosis given that EPE cases can have normal small intestinal wall thickness, and other pathologic conditions can cause small intestine and colonic serosal edema, including salmonellosis, *Clostridium difficile*, and peritonitis.

Clinicopathologic Changes

Hypoproteinemia and hypoalbuminemia, which cause the dependent edema seen in clinical EPE cases, are the most consistent laboratory finding associated with EPE. The pathophysiology of hypoproteinemia and hypoalbuminemia is still under debate. Replication of *L. intracellularis* results in the proliferation and hyperplasia of the rapidly dividing cells of the crypts, leading to an overpopulation of immature epithelial cells lacking microvilli. These immature epithelial cells, with the capability to be secretory, replace mature epithelial cells lining small intestinal villi, likely resulting in a malabsorptive state and subsequent
hypoproteinemia. A malabsorptive state is further supported by evidence that EPE-affected horses experience a diminished ability to absorb glucose. Recent evidence for a protein-losing component of EPE exists based on case reports of acute death following enterocyte infection with *L. intracellularis*. The horses in these reports experienced secondary bacteremia/septicemia and necrotizing enteritis, suggesting that pathogenic bacteria were able to penetrate the mucosal epithelial layer in areas with concurrent *L. intracellularis* infection. It stands to reason that if pathogenic bacteria were able to penetrate through this layer into the bloodstream, protein could be exuded into the lumen of the gastrointestinal tract via those same, damaged areas.

According to Starling’s Law, the hypoproteinemia seen with EPE results in lower plasma oncotic pressure and a net movement of free fluid from the circulation into tissues. It is important to note that total protein and albumin values decrease rapidly in clinical EPE cases as previous work has shown a total protein decrease of 3 g/dL can occur over the span of 4–7 days. Although the actual values are dependent on the laboratory used, total protein concentrations are generally below 5–5.2 g/dL with albumin concentrations below 3–3.1 g/dL. There are a number of conditions that can also result in decreased total protein and albumin levels, including renal disease, peritonitis, pleuritis, salmonellosis, colitis, and intestinal parasites; therefore, it is imperative that a thorough physical examination along with other confirmatory diagnostics be performed before a diagnosis of EPE is made.

Given that *L. intracellularis* infections are located in the intestinal enterocytes and clinical cases of EPE usually lack an intestinal inflammatory response, other clinicopathologic tests such as complete blood counts and fibrinogen levels are not typically useful for EPE diagnosis. Metabolic abnormalities are unusual except in cases with severe diarrhea, chronic cases, or in cases with concurrent disease. Necrotizing EPE cases were found to have varying degrees of leukocyte count abnormalities, and although coagulation diagnostics were not performed, these cases exhibited signs of disseminated intravascular coagulation (DIC). Infarctions of the small intestine and kidneys associated with EPE have also been documented by the author.

### Fecal PCR

Fecal PCR for *L. intracellularis* is a highly specific test that detects sequences of bacterium-specific DNA. However, the sensitivity of *L. intracellularis*-specific fecal PCR testing is variable, given that there are a variety of PCR inhibitors in feces and it is believed that the bacterium is only intermittently shed in the feces of infected horses. Another problem with fecal PCR diagnostics is that fecal shedding stops after 4–6 days of antimicrobial administration. With respect to EPE sample collection, a study concluded that feces and rectal swabs yielded similar PCR results for *L. intracellularis*, demonstrating that rectal swabs can be considered as an alternative sample type for patients with decreased or no fecal output.

### Serologic Testing

Several *L. intracellularis*-specific serologic assays currently exist for use in horses. The first assay to be developed, the immunoperoxidase monolayer assay (IPMA), was initially used in pigs, but has since been adapted for commercial use in horses. Additional tests are also available for use in horses, including a modified version of the IPMA, a blocking ELISA (outside of the United States), and a new indirect ELISA. All of the serologic tests, with the exception of the blocking ELISA, seem to be highly specific for *L. intracellularis* exposure.
All of these tests rely on the detection of *L. intra-cellularis*-specific antibodies, which suggest exposure, but are not necessarily indicative of clinical EPE or ongoing infection. It is important for practitioners to note that the severity of exposure and infection cannot be inferred from the titer because the antibody response of an individual to the bacterium is dependent on multiple factors. Seroconversion in the horse has been documented to occur approximately 14 days following large-dose experimental challenges, whereas most begin showing clinical signs of EPE by day 19–21.\(^\text{23}\) It is essential to combine both molecular and serologic testing given that these modalities have high analytical specificity but may have variable sensitivity, especially early in the course of disease. To the author's knowledge there are only four commercial diagnostic laboratories in the United States that offer serological testing for *L. intracellularis*.\(^\text{a,b,c,d}\)

### Treatment

Treatment of EPE consists of supportive care in combination with specific antimicrobials directed against *L. intracellularis*. Supportive care includes the use of intravenous fluids, colloids, plasma transfusions, parenteral nutrition, and anti-ulcer medications. Colloids typically used include 6% hydroxyethyl starch 130/0.4\(^\text{e}\) administered at 10 mL/kg IV. Plasma can also be given after the hydroxyethyl starch 130/0.4\(^\text{e}\) at a rate of 4–10 mL/Kg IV. The author has noted that in an average 250-kg weanling, the albumin level may increase 0.1–0.3 g/dL for every 1 L of plasma administered. Patients with a protein-losing enteropathy such as EPE may also have decreased antithrombin levels, increasing the risk of a hypercoaguable state. Thus, medications used to prevent platelet aggregation may be of some benefit. These medications may include heparin (40–80 IU/kg SQ or IV TID), clopidogrel\(^\text{f}\) (4 mg/kg by mouth SID loading dose then 2 mg/mL by mouth SID) or aspirin (10 mg/kg by mouth SID or 17 mg/kg by mouth EOD).

The use of antimicrobials that are able to reach therapeutic concentrations within the cytoplasm of the infected enterocyte is required due to the intracellular nature of *L. intracellularis*. Although successful treatment of *L. intracellularis* has been documented with the use of the macrolides (azithromycin [10 mg/kg by mouth SID] or clarythromycin [7.5 mg/kg PO BID]) the author does not recommend the use of macrolide antibiotics in adults or animals greater than 500 lbs due to the increased risk for colitis. Other antimicrobial treatment options include tetracycline-class drugs (oxytetracycline [6.6 mg/kg IV BID for 5 days], doxycycline [10 mg/kg by mouth BID for 2 wk]) or minocycline [4 mg/kg by mouth BID for 7–10 d]) and chloramphenicol (44–50 mg/kg by mouth TID to QID for 1–2 wk). Although some clinical improvement (e.g., appetite and fever) can occur rapidly following treatment, it can take weeks for total protein and albumin levels to normalize.

The vaccine protocol that yielded the strongest immunological responses was intrarectal administration of 30 mL of either the lyophilized (50 dose/100 mL vial) or the frozen-thawed formulation of the avirulent *L. intracellularis* vaccine\(^\text{g}\) given twice, 30 days apart (Fig. 12). The *L. intracellularis* vaccine is safe and the administration well tolerated by horses. Further, the vaccine has not been associated with the induction of clinical disease in pigs or horses, although fecal shedding up to 12 days has been documented following extra-label intra-rectal vaccine administration in foals.\(^\text{40}\)

### Biosecurity Assessment

**Introduction**

When arriving to a farm for routine vaccination care, one should also inquire about biosecurity of the farm, especially if it is a breeding facility. The equine community has always recognized veterinarians as a resource for spreading knowledge and preventing infection. The community's perception is that we are infection preventionists who have the knowledge about the pathophysiology of infectious disease so we must also have the knowledge of
infection prevention, control and epidemiology. Veterinarians now have expanded roles when it comes to biosecurity and biocontainment.

Our intellectual knowledge does not come for free. We must feel comfortable charging for services that include travel time, time spent performing the site evaluation, and time spent writing a report. The author will describe how our practice incorporates a biosecurity and biocontainment program into a practice builder and revenue.

The application of biosecurity and biocontainment procedures is important for equine breeding facilities. A biosecurity assessment should be approached as would a physical examination. The basic objectives are to identify deficiencies in the facility design, standard operating procedures, training, and the animal housing/movement. Before you arrive at the facility you must have the owner(s)/employee(s) dedicated to the evaluation. Just going through the motions of having an evaluation performed to comply with the Occupational Safety and Health Administration may get you nowhere. During your visit you would want to talk to managers and personnel to get a feel of how standard operating procedures are followed. Ask questions such as how are aborting mares, animals with diarrhea, and new arrivals handled? Question several of the personnel to determine whether they are consistent with their answers. Emphasize before you visit the facility that they should change nothing before your arrival. Observe activities and take plenty of photographs. Take notes so that when you leave the facility you will be able to easily recall your findings. Unfortunately, most of the time when we get called out for a biosecurity assessment it is because of an outbreak situation. Ideally, an assessment should be performed under normal circumstances.

One of the targeted elements for disease prevention is the transmission of the infectious agent. We know from previous studies that greater than 20% of foals by 6 months of age will have infectious diarrhea (The National Animal Health Monitoring System Equine 1998 Study). The goal of the biocontainment procedures is to prevent the transmission of that infectious agent to other foals. The transmission of infectious agents requires three elements: a source (or reservoir) of the infectious agent(s), a susceptible host with a portal of entry receptive to the agent, and a mode of transmission for the agent. Identification of areas or processes where transmission of pathogens is likely to occur (control points) and implementation of measures aimed at minimizing the possibility of such transmission, while allowing for reasonable flow and function within the veterinary hospital or animal facility, is an important component of biosecurity (Fig. 13). During the assessment and development of the prevention and control activities targeted to infectious diseases, the weakest link in the chain of infection (agent, transmission, host) needs to be considered for each specific pathogen. In some situations, control of the agent in a specific reservoir may be the best way to reduce disease occurrence. Chlorination of water is an example of destroying an agent in its reservoir or eliminating a possible mode of transmission.

Strategies aimed at the level of transmission need to be tailored to the type of transmission involved. An example of a control activity targeted to airborne transmission is the isolation of the animal to a facility where there is no shared airspace or is located on the premises where no other animals are currently housed. In many instances the best mechanisms to prevent disease occurrence is through modification of the host, such as developing or boosting immunity through active immunization. Other control activities targeted to the host may include improving the nutritional status of a neglected animal or providing chemoprophylaxis (antibiotics) against a variety of agents. Every effort should be made to minimize the contact between animals with a history or clinical signs suggestive of infectious contagious disease or those with confirmed contagious disease and the remainder of the patients or animals at a boarding facility.

In developing control programs, the feasibility of a policy also needs to be assessed. Feasibility or practicality of the policy is dependent not only on the sociodemographic factors but also the operating needs of the facility. For instance, there may be equine facilities that buy and sell horses on a routine basis and will accept the risk of contagious disease outbreaks, such as Streptococcus equi, as the norm, instead of isolating newly arrived horses for a period of time required.

Cost and the availability of resources also need to be considered when developing control strategies. Implementing and maintaining even the most basic biosecurity program requires trained personnel and
an adequately staffed facility with appropriate supervision. Outbreak investigations have indicated an association between infections and understaffing; the association was consistently linked with poor adherence to hand hygiene (Fig. 14).41–43

A surveillance component to an infection control program is essential to gauge the effectiveness of biosecurity policies. The type of surveillance program each facility employs needs to be determined based upon several factors including cost, efficiency, and the number of high-risk cases routinely housed in the facility.

5. Conclusion

Medical conditions in some foals can be prevented with proper biosecurity measures that help decrease the amount of aeroallergens/pathogens in the environment. It is important for veterinarians to be stewards for animals’ health and when called out to administer routine vaccines we should consider offering a biosecurity assessment of the facility proactively to look for ways to improve both hand hygiene and overall animal health.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References and Footnotes

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1. Introduction

The fetal immune system develops in a sterile and protected environment, and therefore lacks antigenic experience. Soon after birth, the newborn is exposed to the “hostile world” of bacteria, viruses, fungi, and parasites. The exposure to these microbes both challenges the health of neonates and drives the maturation of their immune responses. This initial immaturity of the immune response in foals is considered to be responsible for their susceptibility to viral and bacterial infection, such as *Rhodococcus equi* (*R. equi*). *R. equi* remains one of the most important causes of high-morbidity respiratory disease in foals. As such, it is important to understand what part of the naivety of the neonatal immune response is responsible for this susceptibility given that this affects our efforts to reduce the effect of this and other infectious diseases.¹

The immune response of the horse is composed of both innate and adaptive systems to defend against infections. A wide range of distinct cell types comprise the immune system, each of which plays an important role in both innate and adaptive immune responses. The lymphocytes engage in the central role in adaptive immunity given that they are the cells that determine the specificity of immunity-specific antibody production, cytokine secretion, and cytotoxicity. It is their response that directs the effector limbs of the immune response, humoral immune response, and cell-mediated immune response. Other types of cells interact with lymphocytes either in the way of antigen presentation or mediation of immunologic functions. These cells include: cells that eliminate invaders and initiate adaptive immunity during innate immunity such as granulocytes (neutrophils, eosinophils, and basophils), cells that present antigens to lymphocyte such as dendritic cells and monocytes/macrophages. These latter cells represent an important bridge between the innate and adaptive immune responses. Although all of these cells are present in the neonatal foal, their functionality is impaired compared with adult cells.

B Cells

Prior to birth, B cells are immunologically competent, but their production of antibodies is limited in neonatal foals, although immunoglobulin production increases rapidly after birth.¹ As such, passive immunity transferred via colostrum is critical given that immunoglobulins are rarely transferred to the fetus due to epitheliochorial placentation. The relative concentration of immunoglobulins in the colostrum is such that IgG (IgGb>IgGa>IgGT) >IgA.
Among all of the cytokines, the reduced production overall impairment of T-cell function in foals. These cytokines by peripheral T cells in neonatal (Treg), respectively. Decreased expression of type 1 helper T (Th1), type 2 helper T (Th2), type gamma (IFN-\(\gamma\)) to the foal's susceptibility to viral and intracellular infections. This age-related impairment of sub-isotype production is due, in part, to the immaturity of the T cell response in young foals.

T Cells

Functional T lymphocytes are present in equine fetus by day 100 of gestation and are capable of responding to stimulation by day 140. After birth, T-cell populations undergo expansion, similar to that seen in B cells. The numerical increase in the number of circulating T cells is primarily due to an increase in the CD8\(^+\) T-cell population, given that the proportion of CD8 T cells increases nearly 5-fold by the fourth month of age, whereas CD4\(^+\) T cells remain fairly constant with age. This selective expansion is likely in response to the foal's exposure to environmental microbes. This change in T-cell numbers is also associated with an alteration in their functionality as evidenced by their production of various cytokines. Cytokines are potent regulators of innate and adaptive immunity. The expression of key cytokines such as interferon gamma (IFN-\(\gamma\)), IL-4, IL-17, and IL-10 represent the functions of specific T-cell subsets including type 1 helper T (Th1), type 2 helper T (Th2), type 17 helper T (Th17) cells, and regulatory T cells (Treg), respectively. Decreased expression of these cytokines by peripheral T cells in neonatal foals compared with adult T cells suggests an overall impairment of T-cell function in foals. Among all of the cytokines, the reduced production of IFN-\(\gamma\), an indicator of cell-mediated immune response, is considered an important contributor to the foal's susceptibility to viral and intracellular bacterial infections.

Antigen-Presenting Cells

The activation of lymphocytes is primed and modulated by antigen-presenting cells (APC), which function as a bridge linking innate and adaptive immune response. The APC engulf, process, and present antigens to T cells. This antigen presentation to T cells is mediated via surface molecules and the secretion of various cytokines. This APC population is composed of monocytes, macrophages, and dendritic cells, the latter being specialized and highly efficient APC. Not surprisingly, the APC of young foals exhibited decreased expression of these accessory molecules and cytokines. Here again, the maturation of these cells into a more adult-like phenotype seems to occur in response to stimulation by environmental antigens.

Respiratory Immunity

The respiratory tract provides the second largest route of exposure to invading microbes. Unfortunately, the immune system of the respiratory tract in foals is functionally immature. In particular, the mucosa-associated lymphoid tissue (MALT), which plays an important role in the protection of the respiratory tract, is incomplete in foals. The number and competency of immune cells is impaired in foals compared with that of adult horses. In adult horses, MALT in the respiratory tract is composed of nasal-associated lymphoid tissue, pharyngeal tonsils, laryngeal (LALT), tracheal-associated lymphoid tissue, and bronchus-associated-lymphoid tissue. The appearance of the MALT begins in the fetus and gradually develops until 2 years of age. The first appearance of isolated lymphoid nodules occurs in the fetus as early as 9 months' gestation at the vestibule, nasal cavity, nasopharynx, and LALT. The number of nodules shows a marked increase after birth and reaches the adult level by 2 years of age. The nasopharyngeal tonsil forms the largest single mass of lymphoid tissue in the respiratory tract. However, bronchus-associated-lymphoid tissue is not present in the fetus and neonatal foal, and only found in older foals. In adult horses, organized lymphoid nodules and predominately unorganized infiltrates of closely packed lymphocytes are seen in small intrapulmonary bronchi and these structures are absent in the lungs of neonates. Such structures typically begin to appear by 8–22 weeks of life. This age-associated distribution of mucosal lymphoid tissues reflects a gradual maturation of the respiratory immunity in foals. The association of the occurrence of the nodules at specific sites within the tract and the areas where inhaled antigens accumulate suggests an influence of environmental exposure on this development.

Bronchial Alveolar Lavage Cells

Not only does the distribution of respiratory lymphoid tissue in the foals exhibit an age-related development, but the maturity of the immune cells within the lung also follows an age-dependent development. Besides being located in MALT, lymphocytes are distributed diffusely throughout the lung in the walls of the airways, the mucus, parenchyma tissues, and alveolar spaces. Current understanding of foal lymphocyte function in the lung is based mostly on the analysis of bronchial alveolar lavage (BAL) samples. Although lymphocytes compose approximately 40% of the total BAL cells in adult horses, they represent 4–6% of the cells in BAL from neonatal foals, the remainder being macrophages and some granulocytes. Both the absolute
number and the frequency of lymphocytes in BAL fluid has been shown to increase over time. B cells in particular are initially virtually absent at birth, although IgG-, IgM-, and IgA-producing plasma cells appear 1 week after birth and the numbers of the cells reaches an adult level in foals by 12 weeks of age. A reduced number of T cells in the BAL is also seen in foals less than 6 weeks old. This reduced number of lymphocytes present in alveoli and the lack of available lymphocytes to participate in the immune response in foals less than 6 weeks old may have relevance for foals’ susceptibility to pulmonary infection. An impaired function of lung T cells is also evident in neonatal foals as they exhibit low expression of cytokine, particularly IFN-γ. However, over time there is increased expression of this cytokine likely as the result of exposure to environmental antigens. Together, these deficiencies likely provide the opportunity for infections to occur.

Environmental exposure to antigens likely drives the maturation of the immune system. This postnatal exposure leads to both the recruitment of cells into secondary lymphoid sites and can play a role in directing the immune response toward a specific cytokine response. Thus, early exposure to bacterial antigens is thought to favor the induction of Th1-type immunity and prevents the development of allergic and autoimmune diseases associated with Th2 immune responses. As such, the microbiome of the respiratory and gastrointestinal systems plays a key role in the overall development of immune competency in the neonate. Perturbations of these biomes may lead to alterations in subsequent immune responses favoring Th2 over Th1 responses. This contribution of the microbiome in influencing immune development likely represents the underlying mechanism of the “hygiene hypothesis.” However, a recent study found no association between the gastrointestinal microbiome of healthy foals and those infected with *Rhodococcus equi.*

2. Clinical Application

Given the immaturity of the foal’s immune system at birth, several steps can be taken to maximize its effectiveness. Maternal antibodies are an essential component of the initial immune repertoire of the foal. The importance of passive transfer and the need for the foal to acquire sufficient maternal antibodies cannot be overstated. A post-suckling plasma immunoglobulin concentration of 800 mg/dL should be considered the minimum acceptable level. The quality of maternal colostrum is another important consideration, referring to the amount of antibodies present to specific agents. A mare vaccination program, as recommended by the American Association of Equine Practitioners (www.aaeap.org), should be followed to insure the presence of adequate amounts of specific antibodies in the colostrum. Natural exposure of mares to pathogens in the environment can likewise augment her ability to provide the foal with protection. Earlier vaccination of foals that have received insufficient passive transfer or whose mares were not adequately vaccinated should be considered. Although maternal antibodies may inhibit responses to some vaccines, there is little evidence to suggest a long-term negative effect. As such, it is better to vaccinate the foal earlier rather than risk the possibility of it being unprotected. In the case of *R. equi,* where no vaccine is available, the use of Rhodococcal-specific hyperimmune plasma should be considered for foals on endemic farms. Although this treatment will not prevent infection, a single treatment administered after birth can reduce the severity of clinical signs in foals that become infected. Variability in the apparent efficacy of hyperimmune plasma (HIP) in the field may be due in part to differences in obtained antibody levels obtained in treated foals. Other methods of nonspecifically stimulating T-cell immunity in foals will likely be unsuccessful until the foal reaches at least 1 month of age based on recent studies. The overall effectiveness of this approach in reducing *R. equi* infections in the young foal remains uncertain. Likewise, the effectiveness of these treatments in re-directing foal immune responses is also unknown.

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Declaration of Ethics

The Author has adhered to the Principle of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author has provided paid consultation on immunology-related topics to a number of pharmaceutical companies and other related businesses.

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Neonatal Foal and Post-Partum Mare: Evaluation at Time of Foal-Heat

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Evaluation of both mare and foal at the time of foal heat may provide the veterinarian with the first and arguably most important opportunity to meaningfully affect future reproductive performance of the mare, and the growth, development, and future athletic potential of the foal. Author’s address: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070; e-mail: pmorresey@roodandriddle.com. © 2016 AAEP.

1. Introduction
Economic viability of the individual broodmare and the equine breeding industry itself is largely dependent upon live foal production. This is shown to be consistent between various locations at approximately 80% of total mares bred.1–3 Previously reported economic modelling of equine reproduction has determined that maintaining financial viability of the individual broodmare requires that six foals be produced over a 7-year period, with progeny remaining viable to be sold at auction as yearlings.4 Although buyers tend to value mares on the race quality and success of their offspring,5 mares without a consistent record of timely production of progeny will undoubtedly suffer diminished value at auction. Furthermore, whereas foals that experienced hospitalization did not suffer reduced sale price as yearlings,6 prompt detection in a primary setting and timely treatment of problems avoids losses due to rapid and sometimes insidious onset of sepsis and orthopedic issues.

2. Challenges of the Post-Partum Period

Foal
Successful transition to extrauterine life may be complicated by events both before and during parturition. Once exposed to the external environment, the neonate must rapidly develop altered cardiovascular, respiratory, and gastrointestinal function; stand; suckle; achieve coordinated limb movements; and develop defenses against a myriad of infectious challenges. By the period of foal heat, neonates are expected to have achieved adult cardiovascular patterns; transitioned to a monogastric successfully digesting a milk-based diet while dietary and environmental antigen exposure continues unabated; increase body weight between 1–2 kg/day depending on breed; and be able to rise, stand, and ambulate without assistance sufficiently to match the mare’s movements. Although born immune deficient through a lack of pre-suckle antibodies, the foal can successfully mount a response to many infectious challenges once sufficient colostrum has been ingested and immunoglobulins absorbed.

Where the above has not been adequately achieved, common presenting signs of the compromised neonate include depression, weakness, lack of suckle reflex, fever, hypothermia, sepsis, and neurological dysfunction.
It is desirable to maintain a 12-month foaling interval, which is achievable in mares first rebred on their foal heat (average interval to conception in these mares is 25 days). During this period the mare must recover physically from parturition; involute her uterus sufficiently to receive an embryo; re-establish cyclicity at approximately 21-day intervals; initiate and increase lactation to meet the rapidly accelerating nutritional requirements of the foal; and consume feed sufficient to meet all of these demands while conceiving at a subsequent breeding in a timely fashion. However, whereas time of first post foaling ovulation ranges from 7 to 15 days, pregnancy rates in mares ovulating 10 days or more post foaling are greater. Voluntarily not breeding on foal heat by waiting until the second post-partum estrus (around 30 d post foaling) inevitably leads to delayed conception, and eventual foregoing of a breeding season to allow earlier breeding the following year. This lost opportunity significantly affects the lifetime economic return on the broodmare, without reducing ongoing maintenance and opportunity costs. Mating over multiple cycles to achieve pregnancy increases costs; however, this is small compared with the potential future sales revenue of offspring. This repeated attempt at establishing pregnancy, however, will delay the foaling date and potentially decrease the sale price of the yearling.

Live foaling rate per season has been reported as 80%. To achieve this or better, veterinary expenditure is shown in economic models to be a relatively small proportion of the total outlay for a broodmare owner, and performing the necessary rational veterinary procedures to improve overall health and particularly reproductive efficiency are prudent expenditures.

Lactation is a nutritionally demanding time for the mare. Insufficient intake to meet the requirements of lactation results in the loss of body reserves to maintain foal growth, and can reduce reproductive performance. In one study of fat supplementation prior to and following parturition, mares supplemented showed shorter post-partum intervals and fewer cycles per pregnancy, and their foals had higher initial weight gains compared with control mares and their foals. The preferred body condition score for mares foaling and entering early lactation to enhance breeding efficiency has been determined to be 5/9.

3. Examination of the Foal

Gross appearance of the foal is affected by in utero events (Appendix 1). Prematurity occurs when a foal is delivered before the expected gestational length, often after a seemingly uneventful pregnancy. Their relative immaturity as indicated by short soft hair coat, flaccid ears and lips, small skeletal size, and tendinous laxity. Dysmature foals present with an elongated haircoat, erupted incisor teeth, abnormal mentation, a comparatively small skeletal size, and tendinous laxity similar to a premature foal; however, they experience a prolonged gestation. Placental insufficiency is considered a contributing factor. Postmaturity is where an otherwise-normal foal results from a prolonged gestation, being of a more appropriate skeletal size but with a decreased muscle mass. As in utero residence increases, skeletal growth continues taxing placental function, precipitating a relative placental insufficiency.

Disturbances of in utero maturity of the foal predispose the foal to orthopedic, pulmonary, neurological, and infectious pathologies. At birth, a foal is approximately 10% of its mature body weight, reaching 30% by 3 months of age. The most rapid period of growth occurs close to parturition meaning any nutritional or physiological checks at this time may have significant effects. Managerial influence on foal growth is mediated via broodmare health and nutrition governing milk production. Failure to thrive or loss of body weight is an indication of an underlying disease process causing reduced feed intake, inappetence, or catabolism.

Examination of the foal begins with a good history of events at the time of delivery and in the immediate few days afterward. The neonatal foal seeks to achieve sternal recumbency within minutes of birth. The majority of foals stand within 1 hour of delivery, with pony foals requiring less time and larger breeds taking up to 2 hours (range, 15–165 min). Compromised neonates tend to remain recumbent longer. Initial attempts to stand are poorly coordinated in all foals; however, once standing the foal rapidly develops an appropriate posture and moves freely in search of the mare. At the time of foal heat evaluation, the foal should seem coordinated and move freely.

Within 5 to 10 minutes of birth the suckle reflex is present. Foals actively seek to suckle, and even the recumbent foal makes suckling motions into the surroundings. Most foals suckle the mare within 2 hours of birth (breed and size variations) with greater than 3 hours considered an abnormal finding. At foal heat, the foal should be regularly and vigorously suckling the mare, without loss of milk from the mouth or nares.

Checklist for Examination

Behavior and Activity Level

Foals are inquisitive but quickly develop a strong avoidance of handling, seeking shelter on the far side of the mare. If recumbent, the healthy foal is easily roused and quickly seeks the mare for suckling.

Head

The head and face should appear symmetrical. Mucous membranes should be pink and moist. The forehead and nares should be free of milk staining. Eyes should be free from discharge, with clear
corneas and a pupillary light response that is complete but slow compared with adults.

**Thorax**

Respiratory effort should not be labored, and rate should be regular. Palpation of the thoracic wall in a dorsal to ventral direction, beginning cranially and proceeding caudally over all ribs should not detect pain, soft tissue swelling, or crepitus suggestive of rib fractures. This is especially important over the region immediately behind the elbows over the heart. Auscultation should reveal prominent bronchoesricular sounds over the entire thorax. The cardiac rate will be rapid and labile due to excitement. A flow murmur (systolic) will be auscultable on the left side. The presence of a continuous or right-sided murmur is not expected.

**Abdomen**

The abdominal wall should not be tense, and free of pain upon palpation. The umbilical remnant should be pain free upon palpation, dry, and reduced in size from that expected on a newborn foal. The umbilical ring in the body wall should be closely applied to the urachal remnant; however, a small umbilical hernia (<2.5 cm) is common. Gut sounds should be present over all abdominal quadrants. Milk feces are expected over the perineal region.

**Limbs**

Limbs should be free of overt laxity and contracture. A mild degree of carpal valgus is to be expected. Elbows may still be slightly adducted leading to the appearance from directly in front of the foal of the limb being rotated outward. Alignment with the dorsal aspect of the limb better ascertains conformation. The heels should be free of abrasions. Swelling and pain over joints, physes, and tendinous structures should not be present.

**Common Areas of Concern**

**Congenital Disorders**

Congenital abnormalities are generally uncommon. More serious and potentially life-threatening congenital conditions include microphthalmia, cleft palate, significant disruption of appropriate dental alignment (wry nose, severe prognathism, severe brachynathism, “parrot mouth”), scoliosis, arthrogryposis, hydrocephalus, and immune deficiencies. More common and potentially serious conditions that require timely intervention include herniation (umbilical, scrotal, inguinal) and orthopedic abnormalities (limb deviations, tendinous laxity and contracture, supernumerary digits).

Hernia significance depends upon size, location and ease of reduction. Umbilical hernias are not uncommon, being usually small (<2.5 cm diameter) and easily reducible. Spontaneous resolution is expected within a few days when complications are not present (incarcerated viscera, omentum, infection). The presence of heat, pain, or a steady increase in size warrants investigation. Scrotal hernias usually are easily reducible, resolve spontaneously, and only rarely incarcerate intestine (Fig. 1). Abnormal content (thickened amotile bowel wall) is readily apparent with ultrasonography, and concurrent pain is expected. Inguinal hernias appear as soft swellings in the inguinal/scrotal area, and can be confused for scrotal hernias. A rent in the body wall or vaginal tunic allows intestine to dissect along the subcutaneous tissues. Repair is surgical, and if longstanding, ischemia may occur or adhesions may form compromising the intestine.

**Orthopedic**

Ossification of the cuboidal bones occurs within the last 2–3 months of gestation. Immaturity and dysmaturity of the foal therefore can affect this process. Other conditions associated with incomplete ossification include short gestation, placental abnormalities, and maternal illness. Stresses are applied to the lateral aspect of the carpus (intermediate, ulnar, third and fourth carpal bones), and the sagittal plane of the tarsus (central and third tarsal bones). A small degree of carpal valgus causing uneven weight loading of the carpus is common at birth. More severe deviations can distort those cuboidal bones under increased stress (as above), resulting in increasing limb deviation and degenerative joint disease. Varus deformity similarly distorts weight loading across the cuboidal bones. Should incomplete ossification be present, early diagnosis is critical to preserve athletic function. Serial radiographs and restricted exercise (stall confinement) are necessary, with supportive limb casting sometimes needed to preserve alignment and cuboidal bone structure while ossifying.

Where acute lameness is noted, sepsis of physes or synovial surfaces should be considered the primary rule out before trauma is considered. Leukocytosis is an inconsistent finding, although markers of inflammation (fibrinogen, serum amyloid A) are com-
monly elevated. At foal heat evaluation in the healthy foal, fibrinogen will be in the expected adult range, while serum amyloid A will be elevated with >100 mg/L suggestive of sepsis.\textsuperscript{16–18}

**Cardiac**  
Physiological murmur (patent ductus arteriosus) present at birth should only persist for up to 4 days, being resolved at examination during foal heat. This continuous murmur is located near the aortic valve region, and if not accompanied by cyanosis or peripheral congestion, requires no further investigation. Persistence of fetal circulation past this time suggests an anatomic cardiac anomaly (septal defect, valvular incompetence, stenosis) or pulmonary disease rendering pulmonary pressures elevated, increasing cardiac workload, depressing cardiac output, and countering normal cessation of right to left shunting of blood in the extrauterine environment. Holosystolic (continuously audible between S1 and S2) murmurs located in the pulmonic or aortic valves area are flow murmurs and not of concern. Murmurs that warrant further investigation are of high intensity (grade III/VI or greater), associated with signs of exercise intolerance, and persist past the first week of life.

**Respiratory**  
Thoracic excursion is an indication of respiratory effort. An increased rate may indicate compromised pulmonary function, pain, excitement, or fever. Tachypnea during disease is most consistently related to diffuse pulmonary changes. Nostril flaring may also indicate increased effort. Nasal discharge should never be present, a mucoid discharge may indicate a respiratory tract infection, and a milk discharge can be associated with congenital abnormalities (cleft palate, pharynx) or an inability to swallow milk correctly (dysphagia due to botulism, Se deficiency myopathy, hypoxic insult). If suspected, the chest should be palpated to assess for the presence of rib fractures indicated by crepitus and subcutaneous fluid swelling if unstable; however, it is likely that callus formation has ensued over the period between delivery and the time of foal heat examination of the mare. The majority of fractures are adjacent to the costochondral junction. Gross asymmetry of the thoracic cage may be visualized or palpated. Pain and altered thoracic excursion may be seen; this may be manifest as tachypnea and tachycardia. A flail segment (unstable due to discontinuity in more than one place along a rib) may move in a paradoxical fashion although it is likely to have been observed prior to foal-heat examination.

If fractured rib ends are non-displaced or closely apposed, conservative management is indicated, being stall confinement and periodic examination (weekly) until callus formation is complete, usually 2–3 weeks. If fracture ends are unstable, or are impinging on intrathoracic structures (lungs, heart), or signs of hemorrhage are present (anemia, pleural fluid), more aggressive management is indicated, being direct surgical stabilization of the fracture sites.

**Umbilical Region**  
The umbilicus rapidly retracts and heals post delivery. Umbilical herniation appears as a smooth pendulous swelling at the site of the umbilicus. This may be soft and easily reducible, or firm and irreducible if incarceration of content (omentum, intestine) or abscission has occurred. With urachal patency, urine leakage causes wetting of the hair in the umbilical stump area, regional scalding, and dermatitis, which further promotes infection. Heat, swelling and pain upon palpation are found with infection of the umbilical stump. This may ascend caudodorsally along the urachus, umbilical arteries, or cranioventrally along the umbilical vein. Purulent discharge may be evident at the urachal opening in severe cases in addition to episodic or constant urine leakage. General malaise, fever, depression, polysynovitis, septic arthritis, and septic physitis may follow bacteremia sourced from the umbilical infection.

**Integument**  
Skin abrasions, especially those associated with bony prominences near joints, should be closely examined as direct introduction of sepsis into joints is possible with full-thickness defects. Entropion results from a relative excess of skin in the periorbital region in the immediate post-partum period, and if persistent will lead to chronic corneal ulceration. At foal heat, entropion should be absent having been previously addressed, and if present, suggests marked weight loss or significant dehydration. The possibility of corneal ulceration should be ruled out.

**Gastrointestinal**  
At foal heat evaluation, by definition, foal heat diarrhea is likely present in the foal. This represents a normal colonization and maturation phase of the intestinal tract. It should be of short duration (a few days), self-limiting, and cause no overt depression or signs of illness in the foal. Treatment is seldom necessary, and only supportive in nature. Diarrhea that persists longer, increases in magnitude, and results in inappetence, fever, or depression is infectious until disproven. Common pathogens present at this time include rotavirus and Clostridium spp. Severity, onset, and duration of diarrhea suggest presumptive diagnoses while awaiting confirmatory testing.

**Inguinal Region**  
Inguinal and scrotal herniations are usually easily reducible and resolve with time. Colic is rare unless gut becomes incarcerated, this being suspected where the hernia content becomes firm, painful, and
unable to be reduced. If the hernia sack ruptures, edema forms in the inguinal region or ventrally on the abdominal wall, this necessitating surgical correction.

4. Examination of the Mare

Reproductive

The requirement to rebreed the mare prompts examination at foal heat, otherwise no opportunity for evaluation of the mare may be available in the early post-partum period (Appendix 2).

Integrity of the perineum is vital for health of the reproductive tract. Early placement of a Caslick suture post foaling is shown to improve reproductive performance, with mares sutured at 48 hours post foaling having increased pregnancy rates than those sutured at foal heat, making it imperative that any further delay is avoided.19 Ultrasonography of the genital tract beginning at 7–9 days post-partum will allow determination of the time of first ovulation, with those mares ovulating before 10 days known to have a reduced pregnancy rate and higher embryonic losses.20 A decision can then be made to breed if appropriate or induce luteolysis and initiate a more fertile cycle. Uterine involution should be complete at this time, with no evidence of intraluminal fluid. Ovarian activity should be obvious, with follicular development progressing and endometrial edema present.

General Health

Examination of the oral cavity and particularly the teeth is important. As the mare is under considerable nutritional stress, the ability to consume an adequate ration and digest the contents depends upon integrity of the dental arcade. Malalignment and pain compromise mastication, potentially reducing digestibility of the ration and increasing the chances of esophageal obstruction.

Lameness limits mobility regardless of the source (hooves, joints) and may precipitate stress with any associated pain. Ability to forage is reduced, and elevation of stress hormones exacerbates insulin resistance and depresses hormones involved in promoting cyclical activity.21 Close inspection of the hooves and at minimum flexion testing is indicated in the lame foal heat mare.

Skin reflects general health but may in itself undergo pathology. Hypertrichosis and hyperhidrosis are classical findings for pituitary pars intermedia dysfunction (PPID). This may predispose to dermatitis or folliculitis of localized or generalized distribution. Dermatophilosis is relatively common with a characteristic appearance, and while easily treated is not always addressed. Previously unseen sarcoids, cutaneous masses, or neoplastic lesions may also be noticed at this time of closer examination post foaling. In addition to milk production, the mammary gland should be examined for signs of cutaneous trauma, previously unseen tumors or sarcomas, and mastitis.

Endocrine and metabolic dysfunction may be suggested by coat changes (as above) and conformational changes related to loss of muscle mass and abnormal subcutaneous adipose tissue deposition. Areas of note include the tailhead, behind the withers, in the supraorbital fossa, and most significantly, over the nuchal ligament. Other compatible clinical signs include increased water intake, the presence of chronic infections (sinusitis, pneumonia, endometritis, cutaneous), and periods of somnolence. Laminitis in association with fresh grass access, or without a concurrent provoking condition, is suggestive but not confirmatory of insulin resistance.

Feed requirements increase markedly over maintenance once lactation begins, with mares’ dry matter intake regularly achieving 2–3% of body weight,22 with energy and protein needs also challenging to meet. Essential amino acid intake can also be difficult to achieve in the absence of high-quality protein. Where forage quality is average, concentrate intakes should be in the range of 0.5–1% of body weight. Where lower-quality forage is given or intake restricted, larger amounts of concentrates are needed with the caveat that high grain intakes increase the risk of digestive disturbances. Therefore, higher-quality forages should be provided for lactating mares when possible. High concentrate intakes should be divided into two or three servings per day.

5. Timely Interventions and Opportunities to Add Value

Ultrasonography of the Foal

The preferred ultrasound probe for younger foal examination a microconvex probe with a narrow footprint, of higher frequency (5–10 MHz range). Most structures can also be imaged by use of a rectal probe (5–6 MHz range); however, it may be more difficult to achieve an acceptable acoustic window in some locations due to probe length and shadowing by bony structures (e.g., ventral thoracic wall).

Lungs

Ultrasonography allows rapid assessment of the pleural space and superficial lung parenchyma, with deeper structures visible where consolidation or abscessation is present. Placing the probe in the intercostal space parallel to the ribs maximizes the acoustic window; the probe is generally placed perpendicular to the thoracic wall; however, areas shielded by the ribs can be assessed by sweeping the ultrasound beam horizontally. Assessment of the cranial thorax (cranial to the third intercostal space) presents some difficulty given that the triceps musculature covers this area; however, the probe can be placed under the right triceps musculature with the probe angled toward the left shoulder to image the cranial mediastinum. Evaluation of the lung fields
is especially important for those foals with reported periods of recumbency or suspected milk aspiration earlier in life no matter how brief the observed duration.

Normal aerated lung appears as a hyperechogenic line in motion, parallel to the thoracic wall, timed with ventilation efforts. Inflammatory changes appear as comet-tail artifact (hyperechoic lines radiating perpendicularly to the pulmonary surface) resulting from irregularities in the pulmonary margins (Fig. 2). Consolidation and abscessation appear as less echogenic structures replacing the usual hyperechogenic pulmonary surface, and extend into the pulmonary parenchyma. A hyperechogenic delineation between aerated and non-aerated tissue (abscess, consolidated lung) can be noted.

Rib Fractures
Rib fractures are most common in primiparous mares or following dystocia.23 Ribs 3 through 8 on the left side are most commonly affected.24 They have been demonstrated to be more readily detected by ultrasonography than radiography in neonatal foals.25 Rib cortices appear as a continuous hyperechoic line, with discontinuity of the hyperechoic border of the ribs readily noted and suggestive of fracture. Disposition of the resulting fragments is possible to ascertain. Associated hematomas (subcutaneous, intramural) can also be detected and their extent assessed (Fig. 3). Abscessation is possible by hematogenous spread from a remote site.

Umbilical Region
The urachus usually retracts after birth becoming the median ligament of the bladder.26 When regression is uncomplicated, ultrasonography reveals it to be of uniform echogenicity, with a total width adjacent to the bladder of less than 25 mm.27 Infections appear as enlargement and thickening of the umbilical remnant, with hyperechoic to echogenic fluid or rarely hyperechoic gas if anaerobic infection is present.27 Chronic urachal infections may become encapsulated abscesses. The umbilical vein travels along the ventral midline from the external umbilicus to the liver and in health it is a small vessel with a thin wall and anechoic content (diameter at midpoint, 2–9 mm).26 The infected umbilical vein becomes enlarged with longstanding infection causing prominent wall thickening. Lumen content may be anechoic or be highly echogenic. Infection may extend cranially into the liver, resulting in abscessation.

The umbilical arteries travel laterally to the urachus caudally from the site of the umbilicus. They are readily imaged by applying the ultrasound probe transversely across the midline of the ventral abdomen. The arteries are distinct from adjacent structures, being thick walled and containing a hyperechoic center (clotted blood) initially but regress rapidly in the absence of pathology.26 If
infected the umbilical arteries become enlarged, with thickened walls and prominent fluid content. Where individual umbilical arteries exceed 13 mm in diameter, or the combined width of the umbilical arteries and the urachus exceeds 25 mm, infection should be strongly suspected (Fig. 4).

Body Weight of the Foal
A Thoroughbred foal should be able to increase body weight in the range of 1–2 kg/d.28,29 In a study of foals fed milk replacer, during the first 2 weeks of life, weight gain in replacer-fed foals (0.46 kg/d) was significantly \( (P < .03) \) less than those suckling their dams (1.73 kg/d).30 Although compensatory growth is reported, early intervention in situations of foal weight loss or diminished gain minimizes requirement for growth promotion via dietary manipulation later, reducing potential for developmental orthopedic disease. Although a scale is desirable, weight taping to uncover trends is sufficient in most cases. Charts of expected foal weight gain, body weight, and wither height are available.31

Conformation
Equine veterinarians should practice continuously monitoring foals from 2 weeks of age to ensure that conformational issues are detected early and corrective measures can be instituted conservatively, where possible, to minimize the requirement for surgical intervention in more long-standing conditions. Conformation examination should involve observing the foal standing and at the walk. The observer should position themselves perpendicular to the limb, not the foal, given that rotation can give the appearance of limb deviation. A toe-out conformation of the front limbs is common in neonates due to incomplete thoracic expansion, which remedies with increased age and musculature.32

Incomplete Ossification
Where limbs are appropriately aligned, stall rest, exercise restriction, and corrective trimming to maintain a balanced hoof may resolve the condition when ossification is near complete. External coaptation (splints, casts) is required where ossification is poor, and aim to support and maintain a deviated limb in proper alignment. Stopping the splint or cast above the fetlock joint avoids weakening supporting ligamentous structures or promotion of osteopenia. Serial (weekly) radiographs are essential to monitor progress and modify treatment (Fig. 5). Lateral and dorso-palmar views of the carpus, and lateral and dorso-plantar views of the tarsus are recommended. If the condition has not been addressed prior to foal heat examination, and exercise restrictions have not been in place, deformation of the cuboidal bones is highly likely.

Flexural Deformities
If still present at foal heat check, or unmanaged to that time, flexural contracture deformities require aggressive management. Foals that respond within 2 weeks of birth have the best athletic prognosis.32 Conservative management in the form of judicious heel lowering, toe extensions, and controlled exercise (limited small paddock turn out or regular walking) will improve milder cases. Bandaging, splinting, and casting are sufficient to resolve the majority of more affected cases that require external coaptation for correction. Where possible, weight bearing of the limb should be promoted to facilitate elongation of flexor structures. Lightweight splints can be fashioned from PVC pipe. Bandaging should be changed at least every 2 days to help avoid pressure sores. The period of treatment may be prolonged in severe cases, with surgical intervention necessary in the most affected cases that fail to respond to other treatments. Clients should be informed that with persistent distal interphalangeal joint involvement, distal check ligament desmotomy or deep digital flexor tenotomy (salvage only) may be necessary. For intractable metacarpophalangeal/metatarsophalangeal contracture, proximal check ligament desmotomy may be necessary.

The use of oxytetracycline to aid relaxation of flexor structures is well described.33 A dose of 50 mg/kg IV administered slowly, preferably diluted in intravenous fluids (calcium free) is in common usage. Although improvement can be noted with a single dose, daily dosing for 3 days may be required. Monitoring of renal function (creatinine) is prudent, and care should be exercised with use in compromised foals due to potential nephrotoxicity. Efficacy is greatest in the first few days, of life, with diminished response expected in older foals.

Analgesia with nonsteroidal anti-inflammatory drugs (flunixin, ketoprofen) is indicated to alleviate the pain associated with stretching of soft tissues and promote limb loading during exercise. Once treatment is initiated, progress should be monitored daily until an acceptable level of resolution has been achieved.
Fig. 5. A1, Dorsopalmar radiograph of a 320-d gestation foal. Note the rounding of the cuboidal bones and increased joint spacing. A2, Dorsopalmar radiograph of a 320-d gestation foal at 30 d post foaling. Note the marked increase in angulation of cuboidal bone margins and appropriate joint spacing. B1, Lateral radiograph of a 320-d gestation foal. Note rounding of cuboidal bones and increased joint spacing. B2, Lateral radiograph of a 320-d gestation foal at 30 d post foaling. Note the marked increase in angulation of cuboidal bone margins and appropriate joint spacing.
Flexural (tendinous and ligamentous) laxity, although common at birth, is expected to resolve rapidly with exercise. If still present at foal heat examination, initiation of a controlled exercise program and corrective farriery (heel extensions) are required. Bandaging must be carefully applied to achieve protection of volar structure but avoid exacerbation of ligamentous laxity.

Angular Deformities
At foal heat, valgus deviations may be considered normal if mild and are usually present from birth. The exception is incomplete ossification of the cuboidal bones. Varus deviation is a less favorable conformation. At foal heat, carpal/tarsal valgus if minor in degree, does not yet require aggressive management. Corrective farriery (trimming, glue-on shoes) will resolve the majority of minor cases. Conservative management with hoof extensions (medial for valgus, lateral for varus) may be performed for 2–3 months. Metacarpophalangeal/metatarsophalangeal deviations can be similarly conservatively managed for 2–3 weeks; however, due to the more rapid closure of physes in the distal limb, periosteal transection may be necessary soon after this period if resolution has not occurred.

Where external coaptation is necessary for more profound deviations, regular changing of splints (3–4 d) and casts (10–14 d) is advisable to avoid decubital ulcerations. Muscular weakness and tendinous laxity resulting from immobilization responds quickly to time and exercise. Advanced custom fit braces allow movement while promoting alignment.

Axial deformity (bench knees), is not amenable to correction. Similarly, rotational deformities distal to the carpus or tarsus are most likely not correctable. In both cases, the hoof should be trimmed to maintain balance and efforts directed toward managing any metacarpophalangeal deviations from axial deformity.

Gastrointestinal Disease
Given that neonates are very susceptible to gastrointestinal pathogens, it is important to determine etiology of persistent diarrhea with diagnostic sampling (comprehensive PCR panel or culture with consideration of farm history) early in the season (Table 1). A compromised and persistently diarrheic foal presented at the time of foal heat diarrhea may be an index case of an outbreak. Foals less than 2 weeks of age are particularly susceptible to dehydration and secondary bacterial infection. Intravenous fluids and supportive care should be proactively given.

Mare
Dental work is often delayed due to pregnancy, whether for concerns regarding sedation or potential bacteremia in the presence of gingivitis or decay. The nutritional stress the lactating mare faces to meet the needs of the rapidly growing foal necessitates timely and effective dental care. Dental care at reproductive examination during the foal heat period is likely the first opportunity post foaling the veterinarian will have input if foaling and the neonate have avoided complications to that time.

Discussion of nutritional adequacy of the mare at foal heat is timely, given that any weight loss post foaling is likely already evident. Mares that foal in decreased body condition, or those that lose body reserves in early lactation, have reduced reproductive performance requiring more time to initiate cyclicity and more cycles to conceive.11,34 In a study of mares fed under range conditions with limited supplemental feeding, lactating mares in moderate body condition tended to skip a breeding season, and body condition score 5 proved to be marginally acceptable in lactating mares.35 This emphasizes the necessity for close observation of body condition at foaling and in the early lactation period. Condition scoring of pregnant mares is more representative of body weight changes as the weight of the fetus and uterus are discounted. Visual body condition scoring is augmented by palpation of fat deposits, chiefly over the ribs, tail, head, and vertebral spines, which avoids the effects of abdominal distension and elongated haircoat.

Endocrine and metabolic investigation is indicated in those mares with compatible histories or appearances. Mares with PPID may suffer from

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Sample Type</th>
<th>Diagnostic Method</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clostridium difficle</td>
<td>Feces</td>
<td>ELISA toxin A, B</td>
<td>Rapid results (hours), high sensitivity</td>
</tr>
<tr>
<td>Cl. perfringens</td>
<td>Feces</td>
<td>ELISA enterotoxin</td>
<td></td>
</tr>
<tr>
<td>Salmonella spp.</td>
<td>Feces</td>
<td>Culture</td>
<td>Culture: multiple samples (5 minimum) needed to declare negative from infection, may take 3–5 days for results. PCR: rapid result (hours), high sensitivity, useful screen</td>
</tr>
<tr>
<td>Rotavirus</td>
<td>Feces</td>
<td>ELISA</td>
<td>Rapid results (hours), high sensitivity</td>
</tr>
<tr>
<td>Multivalent</td>
<td>Feces</td>
<td>PCR</td>
<td>Rapid results (hours). Cost effective, high sensitivity</td>
</tr>
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persistent uterine infections that are challenging to clear. However, cyclical activity may continue and mares without uterine infection can be bred successfully. In others, cyclical irregularities (anestrus, delayed ovulation) may be present. If these mares are bred, anecdotal reports indicate a lower likelihood of carriage to term and delivery of a healthy foal. Insulin has a major role in the regulation of ovarian steroidogenesis, follicular development, and granulosa cell proliferation in other species. Insulin resistance has been recognized as the major factor related to polycystic ovary syndrome, the most common endocrine disorder in women of reproductive age, characterized by hyperandrogenic chronic anovulation. Although information relating specifically to the mare is scant, abnormalities in cyclicity have been demonstrated in obese mares with reduced insulin sensitivity, being prolonged inter-ovulatory and luteal phases. Baseline screening for adrenocorticotropic hormone can be performed at any time; however, insulin and glucose measurements are best performed after overnight fasting. Recent information suggests concurrent screening for PPID and insulin resistance may be inaccurate.

The average interval from foaling to first ovulation ranges from 7 to 15 days post-partum. Mares that ovulate 10 or more days after foaling overall have pregnancy rates higher than those mares that ovulate on or before day 9. Mares that conceive on foal heat breeding will have a chance to advance foaling date the next year, with those that do not conceive on the first breeding but do conceive on the second estrus (30 d) potentially maintaining a 12-month interfoaling interval. Voluntarily waiting until the 30-day estrus will inevitably lead to a drift toward later foaling dates for the individual mare, with the eventual outcome being an open season to correct late-season foaling. There are significant economic implications for allowing a mare to establish a pattern of progressively later foaling dates. Foal heat breeding of mares should therefore be encouraged; however, significant post-foaling complications (dystocia, retained placenta, endometritis) will decrease success; therefore, such mares are best scheduled for a subsequent estrus period (30 d or advanced with prostaglandin usage).

A practical approach is to examine mares by ultrasonography on days 7 and/or 9 post foaling. Detection of an ovulation prior to that time delays breeding until a subsequent estrus period induced by prostaglandin administered 5 days post examination. Those mares with suitable follicles (>35 mm diameter), appropriate uterine involution, absence of endometrial fluid or echogenicity suggestive of inflammation or infection, and freedom from caudal reproductive tract pathologies (severe vaginitis, cervicitis, overt cervical defects, mural or mesometrial hematomas) are scheduled for breeding dictated by ongoing ovarian, endometrial, and cervical progress. Those mares requiring management of post-foaling trauma, infection, inflammation, or an elective waiting period are managed accordingly. The value of serial ultrasonography of post-foaling mares to detect and resolve pathology, and appropriately schedule for breeding, with respect to the economic outcome of achieving a timely pregnancy cannot be overstated.

6. Summary
The immediate neonatal period is one of considerable challenge to the foal as it adjusts to the demands of extrauterine life. Examination at foal heat is timely to assess musculoskeletal development, nutritional status, and the adequacy of growth. Structures associated with fetal life should have regressed, and major organ systems assumed responsibility for sustaining the foal. The mare is capable of repeat breeding at this time if involution has progressed favorably and ovarian activity correctly timed. The demands of lactation necessitate an adequate supply of nutrition, and the dental and gastrointestinal competence to use feed material. Veterinary input at this time should ensure both foal and mare have reached milestones compatible with continued development toward maturity and potential for rebreeding, respectively.

Appendix A. Examination of the Foal

| Date |
| Name |
| History |
| Birth date |
| Dystocia/events at birth |
| Physical exam |
| Body weight |
| Activity level |
| Head |
| Thorax |
| Heart |
| Lung |
| Ribs |
| Abdomen |
| Umbilicus |
| Limb conformation |

HOW-TO SESSION: LIFE STAGE MANAGEMENT
Appendix B. Examination of the Mare

My Practice
Whatever Street
Nowhere, Any State
Mare foal heat evaluation form

Date

Name

History

Foaling date
Dystocia/events at birth
Nutrition

Physical exam

Body weight/Condition score (x/9)
General appearance
Dental status
Orthopedic status
Concurrent conditions
Endocrine/metabolic status

Reproductive evaluation


References


How to Establish a Healthcare Program for the Aging Horse in Equine Practice

Dianne McFarlane, DVM, PhD, DACVIM, DABVP

1. Introduction
The aged horse population represents a growing and underserved patient base in equine veterinary practice. In fact, in a recent survey of over 11,000 horse owners care of the senior horse was identified by owners as a major health issue of concern, second only to joint problems. Promotion of a healthy aging process should start when horses are in their middle teen years through an owner-veterinarian collaboration designed to proactively identify and resolve problems before serious illness or physical compromise can develop. The key to keeping the old horse active and healthy is vigilant attention and timely intervention to treat problems before they escalate into serious conditions.

2. Healthy Aging in Horses
Aging is a ubiquitous process accompanied by a loss of adaptability to environmental stress or challenge. Several factors likely contribute to the loss of resiliency in the aged, such as impaired regenerative capacity, decreased metabolic efficiency and accumulation of products of lifelong wear and tear. Whatever the cause, loss of resiliency in the aged can contribute to increased susceptibility and severity of many types of conditions in the elderly including inflammatory, infectious, neoplastic, and degenerative diseases. Therefore, early recognition and intervention, or when possible, prevention of disease is a critical underpinning of geriatric medicine.

Establishing a healthcare program for the aging horse is a service an equine practice can provide for clients that is typically very well received. Results of a market research survey of more than 6000 horse owners suggested that owners consider geriatric horse care to be an area of veterinary practice in which increasing client services would be desirable (http://touch.aaep.org/). The goal of an aging horse healthcare program is to extend the “healthspan,” as well as the life span of the equine patients. Currently more than half of horses over 15 years of age are still involved in physical activity, and 25% of them are still competing. Maximizing the number of performance years of a horse is smart both for sentimental and financial reasons, given that the older horse represents years of investment in training. Replacing a well-trained older horse is neither an easily accomplished nor inexpensive task. Programs that involve both the client and veterinarian in a collaborative effort to monitor, record, diagnose, and treat problems as they arise will have the best outcome for extending healthy years for the aging horse. It is important
to recognize that often clients are unaware that their aged horses have medically manageable conditions; much is attributed to old age that is in fact disease.3–4

3. Medical Conditions of the Aged Horse: What Can Your Clients Expect?
Several studies have been performed during the last 10–15 years that have examined the medical problems of aged horses.3–8 These studies have taken different approaches to gather data, such as owner surveys, retrospective analysis of medical records, veterinary examination of randomly selected aged horses, and postmortem examinations. They have examined horse populations residing in different geographic locations including on different continents. Despite the differences in study design and location, the findings were similar, with the types of medical problems reported and their relative frequency comparable among the studies. In addition, it was a common finding that owners often did not recognize medical problems in their old horses.

4. Common Medical Issues of the Old Horse
Lameness is the number-one problem identified by owners and veterinarians in the healthy aged horse population. It is also the number-one reason for loss of use and death. Common causes of lameness in aged horses include osteoarthritis, laminitis, hoof problems, and soft-tissue injuries.

Weight loss is common and is typically multifactorial in aged horses. Factors contributing to weight loss include dental abnormalities, improper nutrition, chronic pain, muscle atrophy secondary to pituitary pars intermedia dysfunction (PPID), malabsorption, and parasitism. In some aged equine populations obesity may be more common than poor body condition. Obesity may worsen other conditions, such as lameness, laminitis, and exercise intolerance.

Colic and gastrointestinal disorders, including esophageal choke occur commonly in aged horses and are a frequent reason for owners of geriatric horses to seek veterinary care. Impactions and esophageal choke are most commonly associated with poor dentition and/or improper feeding. Strangulating lesions due to lipomas or other causes are not uncommon.

Ophthalmic lesions including cataracts, vitreous degeneration, and senile retinopathy were diagnosed in the majority of aged horses in several studies of veterinary examination of aged horses. Although not a disease strictly limited to the older horse, equine recurrent uveitis (ERU) is more common in the older horses; between 25 and 33% of horses >15 years of age will have signs consistent with ERU. Despite the frequency with which pathology is present in the eyes of old horses, loss of vision is not commonly recognized by owners.

Skin problems, including failure to shed, late shedding, or incomplete shedding, dermatophilis, and dermatological tumors are commonly recognized and reported by owners of aged horses. Shedding abnormalities and bacterial skin infections are often secondary to PPID in aged horses, although these clinical signs can also occur with severe debilitation. Common skin tumors affecting the aged horse include squamous cell carcinoma and melanoma.

Endocrine disease, most notably PPID, increases exponentially with age. PPID can cause a plethora of clinical signs in old horses and can predispose affected animals to secondary diseases, such as infections, parasitism, and laminitis.

Chronic respiratory diseases such as heaves in incidence and severity in the aged horse. Heart murmurs and arrhythmias are also more common in older horses, with approximately 20% of horses >15 years having detectable murmurs with >40% of these graded 3/6.4 The most common cause of murmurs in aged horses is due to degenerative valve disease of the mitral and aortic valves.

Exercise intolerance and poor thermoregulation are also typical of the aged horse; typically, the older the horse the worse its exercise tolerance and efficiency of training.10

Key Components to a Senior Horse Healthcare Program

1. Educate clients on problems and special needs of the aging horse.
2. Provide clients a plan for monitoring, recording, and reporting key health parameters.
3. Regularly schedule veterinary examinations.
4. Routinely perform well-horse geriatric health screens.
5. Provide expertise in design of exercise and nutrition routines.
7. Discussion for end-of-life (euthanasia) plan.

5. Educate Clients on Problems and Special Needs of the Aging Horse
Old Horses Benefit From Enhanced Management and Optimized Care
Old horses, similar to old people, are less able to adapt to environmental stress. Therefore, providing good basic husbandry is a critical component in the care of aged horses. Clients should be educated regarding the special needs of aged horses, given that they may be unaware of some of the specific requirements of a geriatric horse. For example, even an old horse that is no longer in work needs timely farrier care given that proper foot care can aid in ease of ambulation for the arthritic animal. Older horses do not thermoregulate as well as younger animals. Therefore, in extreme hot or cold weather proper shelter is important and a longer warm-up and cool-down period is needed with exercise. Typically, older horses are at the bottom of the herd hierarchy, so a safe place to eat and ade-
quate time to finish meals is important. The horse is a social species and aged horses rely on their pasture mates to feel safe from predators; therefore, a pasture companion is optimal. Older animals have decreased ability to digest fiber, impaired nutrient absorption, and increased risk of impactions. Therefore, individualized appropriate feeding programs, timely fecal egg counts (FEC), proper dental care, and ample access to adequate water is necessary. Water should be clean and may need to be warm; ice cold water may not be well tolerated, especially in old horses with sore mouths. Consider providing an educational event for your clients on general management of the aged horse. You might host a seminar, provide an informational handout, direct them to an appropriate Web site or hold a question-and-answer session on a social media platform.

6. Provide Clients a Plan for Monitoring, Recording and Reporting Key Health Parameters

Engage clients in the monitoring of the aged horse’s health. Give the client a mechanism to record the horse’s data; either a folder or notebook for the paper-oriented client or a jump drive or Web site for the more electronically-oriented client. Sections that can be included are below:

2. Body weight and condition scores.
   a. Include directions with figures on how to body condition score (BCS) and how to measure neck circumference.
   b. Provide a spreadsheet or table where clients can enter data for BCS, weight, and neck circumference (Fig 1).
   c. Create periodic graphs to highlight trends (Fig 1).
   d. Have a place for digital images of the horse.
   e. Include cut-off values for when to call the veterinarian.
3. Laboratory data results.
4. Date of shedding and pattern of shedding. Dated photos are useful to document patterns.
5. Time to consume a meal.
6. Exercise data.
   a. Workout schedule.
   b. Time to recovery after exercise.
7. Farrier records including comments and photos of feet.

7. Regularly Scheduled Veterinary Examinations

Geriatric Equine Wellness Examination

Minimally, a geriatric wellness examination should be performed yearly starting when a horse is 15 years old. As the horse ages, the frequency of veterinary examinations should be increased to twice a year due to the high incidence of age-related problems that can be identified. Approach a geriatric wellness examination with the attention to detail of a pre-purchase examination. Remember, the goal is to identify occult problems, such as those described above (see Medical Conditions of the Aged Horse), that may respond to early interventions so close scrutiny during the examination is important. Consider creating an Aged Horse Wellness Program at your practice to encourage clients to subscribe to a whole animal, preventative health approach specifically designed to optimize care of the aging horse.

Plan the timing of the examination strategically. Consider trying to do the geriatric examinations in the spring to allow the timing of spring shedding to be evaluated and again in the fall when the plasma endogenous adrenocorticotropic hormone (ACTH) test is most useful for identifying PPID. Schedule a FEC to coincide with maximum parasite emergence, which for most of the United States will be in the spring and/or fall.

General Appearance

Evaluation of body weight and condition at each visit is critical. A body-weight and a BCS should be performed and recorded in the medical record at every veterinary examination. Digital photos are extremely helpful as well. In addition, every owner should be trained how to BCS and weight tape their animals. Monthly monitoring of this data by owners may help identify early health trends. Review the owner’s data at the veterinary visit and summarize it in your medical records. Consider graphing data for better visualization of trends. It is important to bring the veterinary record with you to the farm so that you can assess progression.
It can be hard to accurately BCS an old horse. If that is the case, a written description of findings should also be recorded. For example, an aged horse may have fat pads at tailbase, a cresty neck, but also show atrophy of the topline with easily palpated ribs. When averaged, the BCS may be a 4/9, which, as a stand-alone entry is not as helpful as stating the specific anatomical findings. Include neck circumference measurements, especially if the horse is regionally or generally obese.

Lameness Examination
Watch the horse move, examine the feet, and flex the joints. In a study of 69 horses >=30 years of age, 100% of them had loss of range of motion of at least one joint. More than half of horses 15 years or older were found to be 3/5 lame when examined by a veterinarian.

Dental Examination
A complete oral examination should be performed on all aged horses. Remember that many of the old horses will have a sore mouth from dental disease or degenerative joint disease of the temporomandibular joint, so sedation and analgesia may be necessary. Always use a speculum and a good light source to ensure a thorough examination. Be conservative when floating the teeth of aged horses. You will not fix a lifetime of dental neglect. Just make the mouth comfortable. Do not over file the teeth or you may worsen the problem if the occlusal grinding surface is disrupted. Remove loose teeth. The goal of dentistry in the aged horse is improving comfort and the ability to masticate feed.

Integument
Make careful observation of shedding pattern and examine closely for skin tumors and signs of dermatitis. Measure and record tumor size with calipers.

Ophthalmologic Examination
A full eye examination including a fundic examination should be performed.

Heart and Lungs
Auscult the horse in a quiet location. Use of a re-breathing bag is recommended. If the horse is still used for performance or pleasure riding, a cardiopulmonary examination focused on recovery after exercise can be informative.

8. Routine Well-Horse Geriatric Health Screens
A well-horse geriatric health screen should include a complete blood count (CBC), serum biochemistry panel, plasma ACTH concentration, serum amyloid A, and a quantitative FEC. A fasting or resting insulin or an oral sugar test is advisable in horses that are overweight, have a history of laminitis, or PPID. Establishing an individual horse’s normal reference interval is ideal. By starting geriatric health screens when the horse is in their mid to late teens, this can usually be accomplished. Normal reference intervals for aged horses are generally similar to that of younger animals; however, when ill, it is common for aged horses to have a mild but significantly greater deviation in their biochemistry values compared with ill younger horses.

9. Provide Expertise in Design of Exercise and Nutrition Routines
Counsel your clients on the importance of exercise and proper nutrition in horses as they age. The overall goal is to maintain an ideal body condition, and keep the aged horse active to optimize flexibility, muscle tone, and strength. As horses age, both exercise and nutritional requirements will change. Therefore, it is advisable to reassess your recommendations at each visit. A common example is the horse that has been obese as an adult and is managed on a diet designed to limit calories and minimize water-soluble carbohydrates. As this horse grows older it may experience an age-associated change in metabolic and endocrine function and start to lose weight. This weight loss can progress rather rapidly, resulting in an overly thin animal if adjustments are not made in a timely manner.

In the thin, aged horse it is important to provide a safe environment to allow ample access to feed. Typically, older horses drop in hierarchal position within the herd, and as a result access to hay or grain will be limited if asked to compete with younger herdmates. Furthermore, the time required to consume a concentrate meal is frequently much longer, causing the older horse to be run off before finishing. Feeding processed or complete senior feeds have been shown to be beneficial in promoting weight gain in thin aged horses. For those with poor dentition or a history of esophageal obstruction, presoaking the feed is advised.

In the obese aged horse, measures should be taken to reduce BCS through limiting caloric intake and reducing water-soluble carbohydrates in the diet, in a similar manner to weight loss in the younger animal. Providing mineral and trace supplements, particularly if hay is being soaked, is especially important in the older animal as nutrient absorption can be impaired with age.

10. Early Interventions for Identified Problems
The overall goal of a geriatric horse program is to be vigilant in observing the horse so that timely interventions can be successful in preventing serious health issues from developing. Therefore, it is important that criteria are communicated to clients as to what constitutes a problem and when to schedule a veterinary visit. Having “call ifs” on the owner’s logs and medical records can be helpful.
11. Discussion for End-of-Life (Euthanasia) Plan

Euthanasia

More than 90% of horses are euthanized rather than die of natural causes. Therefore, it is advisable to have a discussion with the client to help develop an end-of-life plan for the geriatric horse. Most important is having a plan in place on how the horse’s remains will be handled and who will be present at the euthanasia. It is preferable to have this discussion prior to the actual time when the horse is in trouble and actions are needed. For a client, an euthanasia experience is often one of the most important determinates of how favorably they view a veterinarian.

Hospice or Palliative Care

Hospice or palliative care is a service that can be offered to help manage the horse that has a very limited time left before euthanasia or death. The goal is to help the terminal patient remain comfortable for a finite period to allow the horse owner preparation time for the euthanasia. Most often this involves management of pain or loss of mobility or appetite. It is important that the expectations from both the owner and veterinarian be clearly stated, given that management of pain may be different in the animal expected to live for a year or years compared with one being euthanized in 2 days.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

How to Design a Parasite Control Program for the First Year of Life: Focus on *Parascaris equorum*

Wendy Vaala, VMD, DACVIM-LA

1. Introduction

Drug resistance among cyathostomin and ascarid populations is a growing concern for horse operations worldwide. The fact that *Cyathostomina* are not usually serious pathogens in well-managed, healthy adult horses has allowed practitioners and horse owners to remain fairly complacent that such resistance, although warranting caution, was manageable. That comfort level disappeared with reports of drug-resistant populations of *Parascaris equorum* in young horses.1–7 During the first year of life, the most pathogenic parasite encountered by young horses remains *P. equorum* with its potential to cause respiratory disease, ill thrift, weight loss, small-intestinal impaction, peritonitis, and death. Effective control of *P. equorum* should be the litmus test for a successful deworming program designed for juvenile horses. Management practices associated with the appearance of drug-resistant ascarids include a farm history of frequent anthelmintic treatments that begin when foals are younger than 2 months of age and are repeated at regular, frequent intervals without regard to basic parasite biology or anthelmintic susceptibilities.1–8 The environmental longevity of weather-resistant *P. equorum* eggs contributes to progressive accumulation, year after year, of drug-resistant eggs on mare and foal pastures, resulting in a vicious cycle of the current year’s foal crop becoming infected through ingestion of ascarid eggs shed by past generations of weanlings. Without the use of fecal-egg-count reduction tests (FECRTs) to confirm the efficacy of frequently used dewormers, many breeding farms unknowingly have been selecting for the survival of drug-resistant ascarid populations through frequent and repetitive use of drugs that are no longer effective. Results from surveys conducted among stud-farm managers from different countries confirm that despite acknowledging the growing prevalence of drug-resistant ascarids, farm managers continue to rely on traditional, intensive, rotational deworming regimens that rarely employ fecal egg counts (FECs) or veterinarian consultation. Although ascarid infections seem to eclipse the importance of other equine parasites, threadworms, small and large strongyles, pinworms, and tapeworms also must be considered when designing a deworming protocol for older foals and weanlings.

In the United States, the over-the-counter availability of all major classes of dewormers favors an...
increased reliance on chemical control of parasites with less focus on nonchemical management strategies. The widespread frequent use of anthelmintics, often in the absence of any fecal surveillance program or veterinary involvement, has contributed to the development of multidrug-resistant isolates in well-cared-for horse populations of all ages. There are numerous reports of confirmed or suspected resistance in small strongyles to piperazine, benzimidazoles, pyrantel salts, and more recently, macrocyclic lactones (MLs; e.g., ivermectin, moxidectin). Even more disconcerting are reports of cyathostomins and ascarids becoming resistant to more than one drug class. Fortunately, there still are no published reports of drug resistance among cestodes and large strongyle species including *Strongylus vulgaris*.

The design and implementation of an effective parasite control program for young horse populations faces several inescapable but surmountable obstacles. Juvenile horses have a long-recognized, age-related, increased susceptibility to parasite infection and clinical disease as well as a notorious propensity for a decreased response to anthelmintic therapy accompanied by shortened egg reappearance periods (ERPs). In addition, many breeding operations are challenged by the following:

- A high stocking density that limits pasture management options available to control seasonal pasture contamination with parasite eggs and larvae.
- An "open herd" with frequent introduction of new mares and foals harboring unknown prepatent parasite burdens with unknown drug sensitivities.
- A long history of intensive deworming practices for foals and weanlings with treatments commencing at an unusually young age followed by short, frequent deworming intervals, often complicated by repetitive administration of the same class of anthelmintics without benefit of FEC monitoring to verify drug efficacy.
- An understandable reluctance of farm management to deviate from traditional deworming practices that have been followed for years, if not decades.
- Economic restraints that mandate any proposed FEC-based surveillance program must be cost conscious in terms of labor and diagnostic expenses.

Without the promise of any new, resistance-breaking class of dewormer for horses in the near future, it is crucial to prolong the efficacy of the three major drug classes we do have by encouraging horse owners to rely on veterinary advice and properly timed fecals to customize their deworming protocols rather than defaulting to frequent, random administration of anthelmintics. Fecal egg counts, although accepted as an important part of an evidence-based parasite control program, are unlikely to become widely accepted if they are too expensive or offered only as random diagnostic assays. The challenge for veterinarians is to offer (and charge for) a comprehensive parasite control program that incorporates FECs into a farm-wide, herd-based program that combines chemical and nonchemical control strategies.

2. Materials and Methods

Designing a parasite control program for young horses that includes fecal assays and veterinary oversight requires an appreciation of management factors that select for resistance, a working knowledge of parasite and drug interactions, and an understanding of how to use FECs and FECRTs to monitor drug efficacy and customize a deworming program. A brief summary of several recent parasite surveillance trials and surveys will help identify prevailing trends in parasite control practices on a variety of breeding operations. A review of the key parasite life cycles, the mode of action, and efficacy of the three major classes of equine anthelmintics and the advantages of various fecal egg counting methods available will round out the information infrastructure needed to empower veterinarians to feel comfortable providing a more comprehensive approach to parasite control.

Given that an in-depth discussion of parasite biology and anthelmintic resistance is beyond the scope of this article, the reader is referred to other excellent review articles and books as well as the current and comprehensive set of guidelines for equine parasite control strategies available on the American Association of Equine Practitioners Web site (www.aaep.org/custdocs/AAEP Parasite Control Guidelines.pdf).

3. Results

Independent surveys conducted among stud farm managers in the United Kingdom, Germany, New Zealand, Australia, and Kentucky revealed similarities in deworming strategies and attitudes about parasite control. The majority of stud farms still relied upon fixed, interval-based treatments for foals and weanlings. Most farms dewormed youngsters an average of six to eight times a year. In a Kentucky-based survey, greater than 80% of Thoroughbred breeding farms reported using rotational deworming for their young horses with little to no fecal surveillance. On most of those same farms the first deworming treatments were begun before foals were 8 weeks of age, with many operations administering the first dewormer when youngsters were only 4 weeks old. Among European stud farms, an ML-containing anthelmintic, namely ivermectin, was the most popular drug class used in young horses and was often used repetitively during the first year of life. Tetrahydropyrimidines tended to be the second most commonly used product. Among Kentucky Thoroughbred farms the
drug selection was more evenly distributed between the benzimidazoles, pyrantel pamoate, and ivermectin. A recent survey of eight Thoroughbred and Standardbred breeding operations in New South Wales, Australia revealed that most foals received their first anthelmintic between 4 and 6 weeks of age even though FECs documented that patent ascarid infections were most common in foals 3 months of age or older. Among breeding farms surveyed, ascarid resistance to ivermectin was most common, followed by reduced susceptibility to pyrantel. In the Australian surveillance trial, reduced susceptibility of ascarids to fenbendazole was also identified. Drug efficacy often varied between stud farms and regions within each country, which reinforces the importance of evaluating drug resistance patterns on a farm-by-farm basis. Unfortunately, the majority of breeding operations surveyed reported a general lack of reliance on FECs and FECRTs to formulate deworming protocols or to determine which anthelmintics were effective against ascarids and strongyles. Few farms had deworming protocols or quarantine procedures for newly arrived mares and foals. Certain pasture management strategies were more universally accepted whereas other practices varied by region. Rotational grazing was used to varying degrees by the majority of stud farms surveyed, whereas the use of mixed-species grazing of pastures with cattle or sheep was more likely to occur in Europe or New Zealand as opposed to Kentucky. All farms used mowing of roughs, harrowing of fields, and removal of feces to some degree, but the frequency of those practices varied greatly. In Germany, foals on farms fertilizing pastures with horse manure had a significantly higher risk of having patent *P. equorum* infections. When asked how parasite-related illness was recognized, respondents listed unexplained episodes of colic, observation of parasites in manure, unexplained loss of condition, or their veterinarian’s opinion. Despite expressing an awareness of drug-resistant parasites, stud farm managers in Kentucky were only willing to spend more time and money on an FEC surveillance-based approach to parasite control if they could be convinced that doing so would prevent anthelmintic resistance and decrease documented parasite-related health risks for their horses.

Collectively, these surveys concluded that traditional approaches to deworming young horses were unlikely to be replaced by an FEC-based deworming strategy unless veterinarians could convince farm managers of the tangible benefits such a program would have on the health of the individual, the herd, and the farm environment. With that challenge in mind, it is helpful to review the basic life cycles and prepatent periods of key equine parasites, mode of action, and label claims of the major drug classes, FEC assays available, and the value of ERP and fecal egg reduction testing to evaluate the efficacy of a deworming protocol.

Foals and weanlings are likely to encounter some or all of the following parasites during the first year of life: *Strongyloides westeri*, *Parascaris equorum*, *Oxyuris equi*, cyathostomins (> 50 different species exist), large strongyles (*Strongylus vulgaris*, *Strongylus edentatus*, *Strongylus equinus*), and *Anoplocephala perfoliata*. Important features in the life cycles of these parasites are presented in Table 1. A few additional comments are warranted regarding *Strongyloides westeri* and *P. equorum* given that many deworming regimens target very young foals, often unnecessarily, due to a fear of these two parasites.

*Strongyloides westeri*, residing as an adult in the small intestine, is the first nematode to mature in foals with a prepatent period of less than 2 weeks (sometimes as short as 5–7 d). Infective third-stage larvae (L3) can be transmitted to foals via their dam’s milk for up to 40 days postpartum. Foals can also acquire *S. westeri* infections from the environment via oral or percutaneous routes. Larvae undergo pulmonary migration followed by a return to the small intestines where the females embed in the intestinal mucosa. Foals with clinical strongyloidosis may exhibit anorexia, lethargy, and diarrhea. This nematode is usually considered benign unless present in large numbers as supported by observations from field cases that suggest clinical signs of diarrhea are associated with high FECs (> 2000 eggs per gram [EPG]). Interestingly, the prevalence of patent *S. westeri* infections among Thoroughbred foals in Kentucky has waxed and waned during the past several decades, with a much higher incidence of patent infections reported prior to the approval of ivermectin for use in horses. A recent study of foals ranging in ages from 17 to 117 days of age that had never been dewormed revealed a prevalence rate of 30% for patent *S. westeri* infections, which was substantially greater than historical reports from the same geographic area approximately 15 years earlier.

It was hypothesized that this recent increase in *S. westeri*–positive fecals among Kentucky foals was related to the diminished use of ivermectin in response to the increased prevalence of ML-resistant populations of *P. equorum*. The changing prevalence rate for *S. westeri* infection in foals serves as a reminder that changing the use of a single drug class to address resistance among one parasite species may have consequences in terms of other parasitic infections. Less-frequent use of ivermectin may help combat the increase of drug-resistant ascarid populations while potentially facilitating a resurgence of other ML-sensitive nematodes. Thankfully, age-related immunity to *S. westeri* infection is expected to develop in foals by the time they are 4 to 5 months of age.

Equine anthelmintics with labeled efficacy against *S. westeri* are ivermectin (0.2 mg/kg) and oxibendazole (15 mg/kg). Pyrantel pamoate does not have activity against *S. westeri* nor does fenbendazole at the standard “young horse” (e.g., ≤ 18 mo) dose of 10
<table>
<thead>
<tr>
<th>Parasite</th>
<th>Infective Stage</th>
<th>Route of Infection</th>
<th>Migratory Routes of Larvae and Location of Adults Within GIT</th>
<th>Prepatent Period</th>
<th>Length of Adult Parasite</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strongyloides westeri</td>
<td>L3</td>
<td>Oral via milk; Percutaneous or oral ingestion from environment</td>
<td>In immune adult horses, larvae reside in somatic tissues for years; in late pregnant mares larvae migrate to mammary tissues and enter milk by 4 d postpartum. Larvae develop in intestines of susceptible foals.</td>
<td>5–7 d</td>
<td>6–9 mm</td>
</tr>
<tr>
<td>Parascaris equorum</td>
<td>Larvated egg</td>
<td>Oral</td>
<td>Larvae migrate from small intestines (SI) via lymphatics, venules to liver; from the liver L3 migrate through lungs for ~2 wk. L3 rupture through alveoli, enter airways, are coughed up, and swallowed to enter SI and mature to adults.</td>
<td>10–15 wk</td>
<td>50 cm</td>
</tr>
<tr>
<td>Oxyuris equi</td>
<td>Larvated egg</td>
<td>Oral</td>
<td>L3 invade mucosal crypts of cecum and ventral colon; L4 emerge to feed on mucosa; adults reside in distal large intestine and rectum. Eggs are deposited onto perianal skin.</td>
<td>3.5–5 mo</td>
<td>5–8 cm (females)</td>
</tr>
<tr>
<td>Cyathostomins</td>
<td>L3</td>
<td>Oral</td>
<td>Early L3 invade and encyst in cecal and colonic mucosa and submucosa. L4 emerge to enter lumen of large intestine and molt to L5. Depending on the species, developing adults reside in cecum, ventral or dorsal colon.</td>
<td>≥ 6 wk to ≤ 2 y</td>
<td>7–27 mm</td>
</tr>
<tr>
<td>Large strongyles: <em>Strongylus</em></td>
<td>L3</td>
<td>Oral</td>
<td><em>S vulgaris</em> L4 migrates in intimal layer of mesenteric arteries. L5 return to walls of cecum and ventral colon. <em>S edentatus</em> L4 migrate through liver, retroperitoneal space. <em>S equinus</em> L4 migrate through pancreas, abdominal cavity, liver.</td>
<td>6–9 mo</td>
<td>1.5–2.5 cm (<em>S vulgaris</em>); 2.5–4.5 cm (<em>S equinus, S edentatus</em>)</td>
</tr>
</tbody>
</table>

**Abbreviations:** L5, fifth-stage larvae.
mg/kg. However, Drudge and associates demonstrated that a single dose of fenbendazole administered at 50 mg/kg was highly effective against *S. westeri*. Strategic deworming of the mare may help alleviate the pervasive fear of *S. westeri* that still prompts some farms to routinely deworm foals beginning at 2 to 4 weeks of age.

*P. equorum* infection is most common in foals and young horses less than 2 years of age. Immunity typically develops by the time youngsters are 8 to 18 months of age and is believed to be age-related and exposure induced. Following ingestion of larvated eggs from pasture, paddocks, dry lots, or stalls, larvae emerge in the small-intestinal lumen, penetrate the intestinal mucosa, enter the lymphatics, and are transported to the liver. After a period of hepatic migration lasting as long as one week, L3s are carried to the lungs via the posterior vena cava. Larvae erupt from pulmonary capillaries to enter the alveoli. After 2–3 weeks of pulmonary migration, larvae are coughed up, swallowed, and continue the remainder of their development in the small-intestinal lumen. The prepatent period is approximately 10–15 weeks. Clinical signs associated with pulmonary migration include purulent nasal discharge, cough, and mild fever. Large burdens of ascarid larvae and adults within the small intestine have been associated with poor growth, weight loss, unthriftiness, anorexia, and diarrhea. Small-intestinal impaction resulting in colic and occasionally bowel rupture with peritonitis does occur and is often temporally associated with recent deworming using a ML or pyrimidine anthelmintic. If surgical intervention is required to relieve ascarid impactions, the outcome is often guarded due to postoperative complications related to refractory ileus, peritonitis, and systemic toxemia. Although foals and weanlings are considered the most vulnerable population for developing clinical respiratory and gastrointestinal signs associated with *P. equorum* infections, farm managers should be warned that respiratory disease can occur in susceptible yearlings infected in *P. equorum* and surgical colic secondary to ascarid impactions have been reported in youngsters one year of age and older. Ascarid eggs, once passed, become infective within two weeks under favorable environmental conditions. Consequently, biweekly manure removal in mare and foal pastures is highly effective in reducing environmental exposure. Once larvated, *P. equorum* eggs are extremely resistant and can withstand extremes in environmental temperatures resulting in pasture persistence for 5 to 10 years. Interestingly, a well-maintained composting system can attain high enough temperatures to render *P. equorum* eggs nonviable. Cross-species grazing of pastures with either sheep or cattle is another nonchemical control strategy used to reduce pasture egg burdens.

Drugs commonly used in young foals (age ≤ 6 mo) to treat *P. equorum* infections include fenbendazole, oxibendazole, pyrantel, and ivermectin. The drug dosages and ascarid life stages affected are listed in Table 2. When selecting an anthelmintic to control *P. equorum* it is important to distinguish which drugs are adulticides vs larvicides to establish realistic expectations of ERPs following treatment. Larvicidal drugs, if still effective, should be capable of suppressing *P. equorum* egg shedding for a substantially longer time period than adulticides, given that the former drugs eliminate both migrating larval stages as well as egg-laying adults in the intestines. Based on the life cycle of the parasite, the time interval for foals to become reinfected and re-establish a patent infection could be as long as 10–12 weeks following treatment with a larvicide. Adulticides, such as pyrantel pamoate, which only eliminate adult ascarids in the intestines, would be expected to have a shorter ERP given that larval stages unaffected by the dewormer will continue to mature into egg-laying adults in a much shorter time period (≤4–5 wk). If respiratory disease is suspected as a result of pulmonary inflammation induced by *P. equorum* migration, then a larvicidal treatment would be indicated. In young foals, ivermectin is the only anthelmintic with a label claim against migrating ascarid larvae. However, a larvicidal dose of fenbendazole (10 mg/kg every 24 h for

### Table 2. Equine Anthelmintics With Efficacy Against *Parascaris equorum*

<table>
<thead>
<tr>
<th>Anthelmintic</th>
<th>Dosage</th>
<th>Stage of Parasite Affected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fenbendazole</td>
<td>10 mg/kg every 24 h for 5 d</td>
<td>Adults in intestine</td>
</tr>
<tr>
<td>Fenbendazole</td>
<td>10 mg/kg</td>
<td>Effective against adults in intestines and migrating larvae (not labeled for these stages)</td>
</tr>
<tr>
<td>Oxibendazole</td>
<td>10 mg/kg</td>
<td>Adults in intestine</td>
</tr>
<tr>
<td>Ivermectin</td>
<td>0.2 mg/kg</td>
<td>Adults in intestine and L3 and L4 larval stages</td>
</tr>
<tr>
<td>Moxidectin*</td>
<td>0.4 mg/kg</td>
<td>Adults in intestines and L4 larval stages</td>
</tr>
<tr>
<td>Pyrantel pamoate</td>
<td>6.6 mg/kg</td>
<td>Adults in intestines</td>
</tr>
<tr>
<td></td>
<td>13.2 mg/kg</td>
<td></td>
</tr>
<tr>
<td>Pyrantel tartrate</td>
<td>2.64 mg/kg every 24 h</td>
<td></td>
</tr>
<tr>
<td>Piperazine (not readily available)</td>
<td>44 mg/kg</td>
<td>Adults in intestines</td>
</tr>
</tbody>
</table>

* Moxidectin not labeled for foals less than age 6 mo.
5 d) has been shown to be very effective against migrating ascarid larvae,\textsuperscript{47} even ML-resistant isolates.\textsuperscript{48} Considering the growing number of reports from around the world of \emph{P. equorum} populations that have become resistant to MLs, a larvicidal dose of fenbendazole may be the only drug treatment still effective against migrating ascarid larvae.

Understanding the mode of action and spectrum of activity of the three major classes of anthelmintics, benzimidazoles, tetrahydropyrimidines, and MLs enables practitioners to leverage the full potential of each drug class.

The mode of action of benzimidazole anthelmintics (e.g., fenbendazole, oxibendazole) is to disrupt parasite energy metabolism at a cellular level. Time to kill susceptible parasites is generally slower than that of other drug classes. These dewormers provide a broad spectrum of efficacy against large strongyles, cyathostomins, \emph{Parascaris}, and \emph{Oxyuris} infections. Oxibendazole is effective against \emph{S. westeri} when administered at 15 mg/kg. Fenbendazole administered at an elevated dose of 10 mg/kg for 5 consecutive days exhibits larvicidal efficacy against migrating large strongyles and susceptible populations of migrating and encysted small strongyles. Although not part of the label claim, the larvicidal dose of fenbendazole has been shown to kill migrating ascarid larvae.\textsuperscript{47,48} Larvicidal treatment with fenbendazole has been suggested as a possible tool for preventing the inadvertent introduction of resistant ascarid isolates by foals arriving from other farms.\textsuperscript{8} This treatment also has been shown to suppress ascarid egg shedding for at least 8 weeks post treatment.\textsuperscript{4} Although benzimidazoles may be the optimal drug class to control \emph{P. equorum} infections, reports of benzimidazole resistant cyathostomin populations\textsuperscript{10–15} suggest that other drug classes might be better suited for control of drug-resistant small strongyle infections in older, post-weaning-age foals.

Pyrimidine anthelmintics are marketed for horses in North America as pyrantel pamoate, available in paste or suspension formulations and as pyrantel tartrate, available as a pelleted formulation designed to be used as a daily feed additive. The mode of action for these drugs is as selective acetylcholine agonists resulting in rapid, spastic paralysis of susceptible worms that are then usually expelled by intestinal peristalsis. Given that there is no intestinal absorption of the pyrimidine anthelmintics, their effect is confined to only luminal stages of parasites and does not include migrating larval stages. Lack of efficacy against fourth-stage cyathostomin larvae (L4) has been reported.\textsuperscript{49} Pyrimidines are broad spectrum with efficacy against cyathostomin, large strongyles, ascarids, and pin worms. In addition, pyrimidines have demonstrated good efficacy against the equine cestode, \emph{Anoplocephala perfoliata}. The label dose of pyrantel pamoate (6.6 mg/kg) may provide at least 80% ces-
tocidal efficacy\textsuperscript{50} and administration of twice that dose (13.2 mg/kg) affords greater than 95% efficacy against tapeworms.\textsuperscript{51} Confirmed and suspected cyathostomin resistance to pyrimidine dewormers has been reported in numerous countries worldwide.\textsuperscript{16–18,52} Although the pyrimidines are usually considered to be effective against \emph{P. equorum} infections,\textsuperscript{5,6,8} there are a growing number of reports of pyrantel-resistant ascarid populations.\textsuperscript{4} Some researchers have demonstrated that administering pyrantel pamoate at a higher dose of 13.2 mg/kg demonstrates good efficacy against drug-resistant \emph{P. equorum} populations.\textsuperscript{5,53}

The ML drug class contains two subgroups: the avermectins and milbemycins. Both drugs cause neuromuscular flaccid paralysis in susceptible parasites by interfering with the function of glutamate-gated chloride channels found only in neurons and myocytes of invertebrates. Affected parasites can no longer ingest nutrients and die of starvation or are expelled by intestinal peristalsis if they are residing within the gut lumen at the time of treatment. Similar to the pyrimidines, onset of action is rapid and occurs within 48 hours following treatment. Both ivermectin and moxidectin have broad parasiticial activities and are effective against luminal stages of nematodes as well as migrating larval stages of ascarids, large strongyles, and \emph{Strongyloides}. In addition to nematodes, these drugs also exhibit efficacy against arthropods and are useful in the treatment of \emph{Gasterophilus} larvae. Drugs in this class are also effective against \emph{Onchocerca} larvae, \emph{Habronema} and \emph{Draschia}. Moxidectin is more lipophilic than ivermectin, which accounts for its accumulation in fatty tissues, longer elimination half-life, and prolonged ERP. Unlike ivermectin, moxidectin demonstrates efficacy against encysted cyathostomin larvae. Safety profiles also differ. Due to its lipophilic nature, moxidectin becomes highly concentrated in serum when it is administered to horses with very little body fat, such as foals or thin, debilitated individuals. The immature blood brain barrier of young foals renders them more susceptible to moxidectin toxicity. Signs associated with toxicity include dyspnea, depression, weakness, ataxia, coma, and seizures.\textsuperscript{54,55} In the United States, moxidectin is not labeled for use in foals less than 6 months of age.

Provided the ascarid population on a given farm is not ML resistant, ivermectin exhibits good efficacy against \emph{P. equorum} larval and adult stages. However, reports of ML-resistant ascarids are widespread and worldwide.\textsuperscript{1–8,56} If ivermectin-resistant ascarids are identified in pre-weaning-age foals, it is the author's experience that moxidectin will be ineffective in clearing ascarid infections in older weanlings and yearlings on the same farm. Macrocyclic lactones continue to demonstrate good efficacy against cyathostomin at 14 days post-treatment and large strongyles remain susceptible. However, there are reports of the strongyle ERP becoming
shorter after treatment with both compounds in this drug class. When first marketed, ivermectin and moxidectin suppressed strongyle egg shedding for 8 weeks and 12–16 weeks, respectively. Recent reports have documented reduced ERPs of less than 5 weeks for ML anthelmintics. Additional studies have demonstrated that L4 small strongyle larvae residing in the intestinal lumen are able to survive treatment with MLs.

The two most popular fecal egg counting techniques are the modified Wisconsin method, that involves centrifugation and flotation using a Sheather’s sugar solution and can detect egg counts as low as 1–5 EPG; and the McMasters technique, which relies on flotation using one of several solutions (e.g., saturated salt, saturated sugar-salt, ZnSO4, or Sheather’s sugar) and the use of a calibrated counting chamber, and has a lower limit of detection of $\leq 25–50$ EPG. The modified Wisconsin method offers an increased likelihood of observing cestode eggs if present and is the preferred method to use when performing a FECRT due to its low egg detection limit. Fecal samples collected for either method should be as fresh as possible and stored in airtight containers to reduce egg hatching. If refrigerated, fecal samples can be stored for at least 5–7 days. The reader is referred to other references for details regarding sample handling and storage as well as detailed testing procedures.

The FECRT is the only method currently available to determine whether anthelmintic resistance is developing. Originally designed to evaluate resistance among strongyle species, the FECRT has also been applied to ascarids, although results should be interpreted cautiously. To perform a FECRT, a fecal sample is collected prior to deworming and 10–14 days following treatment. The numbers of EPGs in the pre- and post-treatment samples are used to calculate the percent reduction in FEC using the following equation:

$$\text{FECR} = \frac{\text{EPG (pre-treat.)} - \text{EPG (14 days post-treat.)}}{\text{EPG (pre-treat.)}} \times 100 = \text{FECR (％)}$$

The FECRT can be used for each horse individually, but in the interest of economics and labor, it is often sufficient to test groups of individuals previously identified as moderate to high shedders. The FECR values obtained from those groups are used to infer drug efficacy for the farm. Horses should not have received anthelmintic treatments for at least 8–10 weeks prior to performing the FECRT. If moxidectin was the last drug administered it is preferable to wait at least 12–14 weeks before collecting a pretreatment sample. The FECRT can also be used to screen newcomers arriving on the farm. Only foals old enough to be shedding parasite eggs should be included in the screening. Shedding of (small) strongyle eggs typically does not commence until foals are 6 weeks of age or older and ascarid eggs usually do not develop in fecals until foals are at least 8–12 weeks of age. Egg-counting techniques with greater sensitivity should be used to calculate FECR and only animals with high-enough pretreatment egg counts (e.g., $\geq 100$ EPG) should be included. Given that variability among individual animals can be quite extreme, FECR should be determined for at least five to 10 animals within a farm population and then the average FECR calculated for the group tested. Guidelines for interpreting FECRT results are presented in Table 3. It is important to recognize that efficacies differ among the various anthelmintics. The values presented in Table 3 are suggested cutoff values to use to decide whether parasites are still susceptible to a given drug if there is evidence of developing resistance or if widespread resistance exists.

ERP is defined as the time interval between the last effective deworming treatment and the resumption of significant egg shedding. Table 4 lists the ERP for commonly used equine dewormers. Occasional monitoring of the ERP for a given drug class on a farm is a reasonable way to determine whether resistance is beginning to develop against drugs previously considered effective. A shortening of the ERP is considered a precursor to the development of resistance.

### Table 3. Anthelmintic Efficacy: Interpretation of FECR Values Used to Determine Anthelmintic Efficacy Against Small Strongyles

<table>
<thead>
<tr>
<th>Anthelmintic</th>
<th>FECR When Drugs Were First Introduced to Market</th>
<th>FECR Suggesting no Evidence of Resistance</th>
<th>FECR Suggesting Suspected Resistance</th>
<th>FECR Indicative of Resistance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzimidazoles</td>
<td>99%</td>
<td>$\geq 95%$</td>
<td>90–95%</td>
<td>$&lt; 90%$</td>
</tr>
<tr>
<td>Pyrantel</td>
<td>94–99%</td>
<td>$\geq 90%$</td>
<td>85–90%</td>
<td>$&lt; 85%$</td>
</tr>
<tr>
<td>Ivermectin/moxidectin</td>
<td>99.9%</td>
<td>$\geq 98%$</td>
<td>95–98%</td>
<td>$&lt; 95%$</td>
</tr>
</tbody>
</table>

Adapted from AAEP Parasite Control Guidelines.

### Table 4. Cyathostomin Egg Reappearance Periods (ERP) for Commonly Used Equine Anthelmintics

<table>
<thead>
<tr>
<th>Anthelmintic</th>
<th>Expected ERP When Drug Is Still Effective</th>
<th>ERP When Drug Was First Introduced</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzimidazoles</td>
<td>4–5 wk</td>
<td>6 wk</td>
</tr>
<tr>
<td>Pyrantel</td>
<td>4–5 wk</td>
<td>5–6 wk</td>
</tr>
<tr>
<td>Ivermectin</td>
<td>6–8 wk</td>
<td>9–13 wk</td>
</tr>
<tr>
<td>Moxidectin</td>
<td>10–12 wk</td>
<td>16–22 wk</td>
</tr>
</tbody>
</table>

Reprinted from AAEP Parasite Control Guidelines.
full resistance. When monitoring the ERP it is only necessary to collect fecals from a subset of the resident population (often the horses classified as higher egg shedders). As an example, if ivermectin was last used, the expected ERP is 6–8 weeks. Collecting fecals from a group of young horses 4 weeks after ivermectin treatment will help determine whether the drug is still suppressing strongyle egg counts as long as expected.

4. Discussion

Despite the increasing prevalence of drug resistant *P. equorum* populations on breeding farms worldwide, deworming programs for young horses have undergone minimal changes during the past several decades. Contemporary surveys of stud farm managers suggest that some of the reluctance to modify traditional, often intensive, interval-based deworming protocols is due to their uncertainty that adopting a more comprehensive, surveillance-based approach to parasite control with a focus on *P. equorum* will result in tangible, measureable benefits for the farm. Conditions are ideal for veterinarians to market their knowledge as well as diagnostic fecal assays. Continue to enlighten stud farm managers and foal owners about the health risks associated with clinical and even subclinical *P. equorum* infections. Without proper diagnostics, including FEC, upper respiratory tract disease secondary to ascarid larval migration could easily be mistaken by lay personnel for viral or bacterial infections. Foals experiencing chronic, ascarid-induced pulmonary inflammation might be more susceptible to other opportunistic respiratory pathogens. Suboptimal growth and poor body condition among weanlings may not be nutritional in origin but the results of *P. equorum* infection. The well-known threat of ascarid-induced impaction colic affects not only weanlings, but has been reported in yearlings and young adults as well. These potential health risks may help convince foal owners and breeding farm managers to invest in an FEC surveillance program to ensure their deworming program is effectively controlling indigenous *P. equorum* populations.

Before making any deworming recommendations, consider providing a physical examination of individual farms using a simple questionnaire to capture information about management practices, herd demographics, and deworming history. Assess the farm in terms of stocking density, size, and overall condition of pastures/paddocks and labor available to help decide which nonchemical parasite control strategies are realistic and feasible for that particular operation. Obtain a detailed history about anthelmintic use spanning at least the past 3–5 years with a focus on when foals receive their first dewormer, the frequency of treatments, and which drug classes are routinely administered during the first year of life. Summarize results of any fecals that have been performed. Document if there have been any suspected or confirmed cases of parasite-related disease in foals, weanlings, or yearlings.

Using information obtained during the farm visit, customize a parasite control plan that begins with strategies to reduce environmental parasite egg and larval burdens. These husbandry options include cross-grazing pastures with other ruminant species, keeping pastures mowed to remove roughs, harvesting a hay crop at the end of the grazing season, and resting pastures for at least several months during periods of warm ambient temperatures sustained above 85°F to optimize dessication of vulnerable strongyle larvae. If pastures are harrowed, remind owners that this procedure should only be performed during hot, dry periods and pastures rested for 3–4 weeks or longer before reintroducing mares and foals. Bi-weekly manure removal from favorite loafing areas for mares and foals such as around run-in sheds or near gates and waterers remains one of the most effective methods to reduce exposure to infective larval stages. Although fresh manure should never be spread on active pastures, properly composted manure can attain high-enough temperatures to kill both strongyle larvae and ascarid eggs. If possible, foals and weanlings should be turned out onto the farm’s cleanest pastures.

Before a deworming protocol can be designed it is necessary to determine which drug classes are effective against ascarids and cyathostomins on that particular farm. Prior to weaning, focus on control of *P. equorum*. In the older weanling control of small and large strongyles and tapeworms must be considered. Begin with an easy-to-implement FEC surveillance program that is economical and labor friendly in terms of sample collection. Agree on basic guidelines for the program. One common goal is to protect the health of the individual foal or weanling while simultaneously minimizing egg shedding using the fewest number of drug treatments possible. Unless medically indicated, delay the first anthelmintic treatment for foals until they are 2–3 months of age. Reasons to consider therapy at a younger age include treatment of confirmed, clinically symptomatic *S. westeri* infections or clinical suspicion that foals are harboring dangerously high burdens of migrating ascarid larvae. On farms accustomed to deworming foals younger than 8 weeks of age, consider screening a group of 2–6 week-old foals to demonstrate the lack of any significant fecal egg shedding prior to 8–10 weeks of age. These results reinforce the time required for ascarid and cyathostomin infections to achieve patency and may help farm managers feel more comfortable about pushing back the age for first drug treatments without worrying about foals contaminating pastures with high egg counts. If fear of *S. westeri* is a reason for early drug treatments, re-examine the deworming strategies for the periparturient mare to deflect unnecessary drug treatments away from young foals. Ivermectin administered the month before foaling or within the first couple of days post-
partum remains a popular drug choice. Oxibendazole administered at a dose of 15 mg/kg is a reasonable treatment for foals with clinically significant and symptomatic *S. westeri* infections.

To determine which of the three major drug classes, (e.g., benzimidazoles, tetrahydropyrimidines, and MLs) are still effective against *P. equorum*, perform a FECRT on samples from foals with patent strongyle infections (e.g., positive FECs). To maximize efficient use of labor, the timing of these fecal collections can coincide with a farm visit to screen foals for *Rhodococcus equi* pneumonia or to administer vaccines or check mares for pregnancy. The fecal assay used should be reasonably priced and sensitive. Consider training a technician to perform the FEC in house to reduce overhead and cost to the client while generating a modest profit. When performing FECR calculations to evaluate drug efficacy, the author prefers the modified Wisconsin method due to its low egg detection limit. This method also increases the likelihood of detecting cestode eggs.

If ivermectin resistance is identified among indigenous *P. equorum* populations, then pyrantel pamoate and fenbendazole or oxibendazole are the remaining drug classes to consider. On some farms using the higher dosage (13.2 mg/kg) for pyrantel pamoate improved efficacy against resistant ascarids. Likewise, there are two different dosages to consider when administering fenbendazole to juvenile horses. A dose of 10 mg/kg is recommended for youngsters less than 18 months of age. If ascariid resistance is detected at this dose, a larvicidal dose (e.g., 10 mg/kg administered once daily for 5 d) should be considered based on the reports of efficacy against both larval and adult stages of *P. equorum*. It has been the author’s experience that the larvicidal dose of fenbendazole has been effective at reducing *P. equorum* egg shedding when the single 10-mg/kg dose has proven unsatisfactory. Hopefully adequate ascariid control can be achieved with two effective drug treatments administered prior to weaning. On farms with open herds, evaluate quarantine procedures for newly arrived foals and leverage the use of a larvicidal treatment with fenbendazole coupled with a FEC to reduce the risk of introducing drug-resistant ascarids. Close to weaning time, consider evaluating FEC in a representative group of foals as a screening tool to see whether the pre-weaning drug treatments targeting *P. equorum* have been successful.

Among older weanlings, collect fecals from a representative group just prior to the next planned drug treatment. Use the FEC results to identify foals with patent strongyle infections that can be used to test drug efficacy against that group of parasites. The same three drug classes should be tested using the FECRT. Although there are numerous reports of benzimidazole-resistant cyathostomins, do not assume resistance is present until it is confirmed on that particular farm. Recent surveillance trials using FECRT have shown that drug-resistance patterns can vary between facilities within the same state. In some instances older weanlings may be shedding both ascariid and strongyle eggs and a single drug class might not be sufficient to control both nematodes. In this situation consider administering two different drug classes simultaneously. This strategy has been used successfully on farms with confirmed multidrug-resistant parasite populations. If tapeworm infection is a concern, then one treatment administered between 6 and 12 months of age should include an effective cestocide such as the higher dose of pyrantel pamoate or dewormer containing praziquantel.

On larger breeding operations it might be possible to evaluate the efficacy of all three drug classes within one breeding season, given that different groups of foals can be used to test different anthelmintics. On smaller operations with fewer foals, it will probably require several foal seasons to test all the drug classes against both ascariid and strongyle populations. It is helpful to remember that not every foal needs to be tested every time. If drug-resistant parasites are detected it is likely to be a farm-wide problem rather than an individual animal problem.

Although this article has focused on the foal and weanling, it is naive to forget that broodmares represent an important and intimate source of parasite exposure for their foals through nematode eggs and larvae shed in their feces or through their milk. An effective deworming program for the broodmare band helps control overall pasture parasite burdens awaiting each new crop of foals.

5. Summary

Deworming protocols for young horses during their first year of life have three major goals: prevent and/or decrease the incidence of parasite-related disease in individual animals, reduce environmental contamination with parasite eggs and larvae, and accomplish the first two goals using the minimal number of effective drug treatments. Administration of ivermectin to the periparturient mare should eliminate the urge to treat neonatal foals due to a fear of *S. westeri*. Prior to weaning, *P. equorum* is the primary pathogen of concern and should be the focus of anthelmintic treatments in foals 6 months of age and younger. Ideally, foals should receive their first treatment just as ascariid infections achieve patentcy at approximately 2.5–3 months of age. Benzimidazoles and tetrahydropyrimidines are the two drug classes most likely to demonstrate efficacy against ascarids. ivermectin should only be used if efficacy is confirmed using the FECRT. Each drug class should be evaluated periodically on a farm by farm basis to ensure lack of resistance. After weaning, control of small and large strongyles and tapeworms becomes a consideration in drug selection. Macrocyclic lactones are a reasonable option for strongyle control. Praziquantel or a double dose of...
Pyrantel pamoate are the only choices for cestode treatment. Figure 1 outlines a chronological approach to parasite control during the first year of life.

Strategic use of affordable and sensitive FECs to provide farm-specific deworming guidelines combined with the implementation of realistic nonchemical parasite control strategies are critical to the success of any deworming program and can be an important, billable veterinary service. This comprehensive approach can be expanded to include other age groups on the farm.

**Acknowledgments**

**Declaration of Ethics**
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**
The Author is employed by Merck Animal Health, a company that manufactures equine anthelmintics containing fenbendazole.

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Immunosenescence and How it Affects Care of the Older Horse

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1. Introduction

During the past century, improvements in health care and advancements in science and medicine have extended the average life span of humans and companion animals, including horses. We are now facing new challenges with the paradox of an older horse population with increased longevity and the potential of increased age-associated diseases. Thus, a better understanding of the mechanisms leading to a decline in physiologic function with age is important in providing optimal care of old horses. The process of aging is a ubiquitous complex phenomenon and although there is no universal definition of aging, the effectiveness of several physiological systems becomes compromised. One of the most-recognized consequences of aging is a decline in function of the immune system. This introduction will start by discussing the prevalence of old horses, followed by conditions of the aged horse. It will then go on to discuss the two main terms that define a declining immune system of the old horse: immunosenescence and inflamm-aging. Lastly, we will mention how nutrition may affect the immune system of old horse.

Definition and Prevalence of the “Old” Horse

When does a horse become “old?” The term “old” has a broad meaning of “lived for many years; not young.” Some refer to the “old” as being “geriatric” or “aged,” which implies there are health problems occurring with the process of aging. However, there is considerable variation in the aging process and there is no set chronological age at which an individual is considered “old.” This is due to the fact that chronological age does not equal biological age. Chronological age is simply an individual’s age in years. Biological age is one’s age at the cellular level.¹ These two numbers are oftentimes not equal. Some horses remain physically active and healthy well into their twenties and yet others become biologically “old” or “geriatric” by mid to late teens. These individual differences are due to a variety of factors including genetics, environment, and management practices to name a few. For the purposes of this review we will refer in general to the aged horse as being “old” rather than geriatric. With regard to chronological age for an “older” horse, we will use ≥20 years of age, given that this is a common age cutoff used in scientific studies when comparing physiological responses of “old” horses to “younger” horses.

Descriptions of the aged horse population statistics are limited to a few. In 2003, Brosnahen and Paradis² surveyed horse owners and they perceived their horses as being old at approximately 22 years
of age. Data from a retrospective study showed that in 1989 only 2% of equine referral cases at a university veterinary hospital were greater than 20 years of age but this had increased to 12.5% by 1999 and to approximately 20% by 2003. However, in 2005 a survey of the horse population in the United States reported only 7.6% of the total population to be greater than 20 years of age. It has been estimated that 29% of the United Kingdom equine population is 15 years or older.

Clinical Conditions Associated With Aging

There are several clinical conditions that are acknowledged as being more prominent in the older horse. And although these conditions may be present in younger horses, the problem increases with age. In a survey conducted in 2005, owners considered approximately 43% of horses (≥20 y) to be suffering from health disorders compared with approximately 33% in the 6–10-year-old age group.

The most frequently reported problems in horses 20 years and older fall into the category of gastrointestinal, musculoskeletal, and respiratory problems. In a more recent survey, owners were most concerned with weight loss, arthritis and lameness, and dental problems in caring for "old" horses. The most commonly cited clinical conditions of the "old" horse are the following: pituitary pars intermedia dysfunction (PPID); other neoplasia including intestinal lipomas, melanomas, and squamous cell carcinomas; colic; dental abnormalities; glaucoma; decline in cardiac output; respiratory function decline; osteoarthritis; decline in reproductive function of the mare; and increased risk for bacterial and viral infections. Toward the latter, a decline in immune function likely contributes to this increased risk of certain conditions with aging in the horse.

Immunosenescence and Inflamm-Aging

It has been appreciated for many years that the immune system undergoes gradual deterioration with age, referred to as immunosenescence. The classic view of immunosenescence has recognized age-related changes of the immune system as unidirectional declines in function. However, recent studies suggest that this process is more complex in which nearly every component of the immune system undergoes age-associated changes leading to both diminished and enhanced "inflamm-aging" characteristics. The two terms, immunosenescence and inflamm-aging, may sound contradictory; however, they are intertwined as reviewed below.

Immunosenescence is the biological aging process associated with the progressive decline in overall systemic immunity and increased prevalence of cancer, autoimmune and chronic diseases, poor responses to vaccination, and increased susceptibility to common infectious diseases. As reviewed, both innate and adaptive arms of the immune system are affected by immunosenescence with a wide range of cell types of the immune system including: 1) hematopoietic stem cells, lymphoid progenitors in the bone marrow and thymus, thymic stroma, macrophages, dendritic cells, and neutrophils of the innate response; and 3) B-cells and T-cells.

Horses, like other species, experience thymic involution. Few studies have investigated the innate immune system of the horse. To date, the innate immune system of the horse seems to remain intact with age. A study by Horohov and colleagues demonstrated that aged horses (mean age, 25 y) had lymphokine-activated killer cell activity equivalent to that of younger animals (mean age, 7.5 y). Circulating monocyte and granulocyte counts in young and aged horses are also reported to be similar. These findings are in concordance with those of human studies, as are the below studies investigating the adaptive immune system of the aged horse.

Studies have looked at age-associated changes in lymphocyte populations (≥20 y) and found that old horses exhibit a decline in the total lymphocyte count, as well as lymphocyte subset cell counts (CD5+, CD4+, and CD8+, and B-cells). There are no significant differences in the immunoglobulin (Ig) isotypes in aged horses compared with younger controls, although there was a trend toward a higher concentration of IgA and IgG.

Among the immunological changes in aged humans and experimental animals, T cells are most frequently found to be responsible for defects in humoral and cell-mediated immunity. Moreover, dysfunctional T cells have been shown to be correlated with increased morbidity and mortality in the elderly. The most noted changes in T cell populations of the elderly are decreased naïve T cells, expanded pools of dysfunctional memory T cells, shrinkage of the T cell repertoire, and decreased T cell proliferative responses in vitro. In fact, decreased T cell proliferation is a hallmark characteristic of immunosenescence in many species including, humans, primates, mice, cats, and horses.

Proliferation of T cells or clonal expansion is essential for maintaining function of the adaptive immune system. During development, T cells generate receptors that will allow recognition of all the possible antigens they will encounter over the life span (Janeway et al., 2005), so that when a lymphocyte generates and expresses its antigen receptor, that receptor specificity does not change. Thus, antigen specificity is maintained as lymphocytes divide and mature into effector cells, which are involved in clearance of the antigen. Once this occurs most of the cells die by apoptosis, leaving a small number of memory cells with the same antigen-receptor specificity. Repeated exposure to antigen results in the process of activation and proliferation begins again. T-cell proliferation is critical because there are an infinite number of antigens that could be encountered over a lifetime when com-
pared with the number of cells that can respond to a single antigen.42,43 Thus, proliferation is an important process in generating sufficient numbers of T cells to fight an infection.

Mechanisms responsible for decreased proliferation are not completely known. In one study of aged horse immunosenescence, T-cell proliferation remained depressed after supplementation with recombinant interleukin (IL)-2, suggesting that decreased proliferation cannot be solely attributed to decreased expression of IL-2.27 Telomere-driven replicative exhaustion has been proposed as mechanism leading to immunosenescence in both T and B lymphocytes. Telomeres are specialized protein structures that cap and protect the ends of chromosomes to maintain stability and integrity of the DNA. Telomeres shorten with each cycle of cell division, and sufficient telomere loss acts as a molecular clock that triggers cell senescence. Progressive telomere shortening with age in humans has been demonstrated in many studies and this age-associated loss of telomeres has been observed in different types of leukocytes. In fact, we have recently shown that this age-associated loss of telomeres occurs in equine peripheral blood mononuclear cells and was correlated with decreased proliferation potential and other immunosenescent characteristics.44

Inflamm-Aging and Consequences

A lifetime of exposure to antigens such as influenza and herpesvirus just to name a few can have an effect on immunosenescence and contribute to the process of inflamm-aging by a theory known as clonal exhaustion.45 In fact, latent viral infections in elderly humans such as cytomegalovirus have been shown to be highly associated with a chronic, low-grade, pro-inflammatory state called, inflamm-aging.18 Although this exact association has yet to be determined for the aged horse, the process of inflamm-aging has been well characterized.

Inflammation is a complex networking of molecular and cellular interactions directed to return physiological homeostasis.46 Unlike acute inflammation, chronic inflammation is not resolved within minutes or hours but involves immune responses, in particular cytokine production, tissue injury, and healing that occur over a long period.46 It’s an imbalance between pro- and anti-inflammatory cytokines that contributes to the process of age-associated chronic inflammation. Pro- and anti-inflammatory cytokines are released by cells of both innate (dendritic cells, monocytes, macrophages, and NK cells) and adaptive systems (lymphocytes). Pro-inflammatory IL-1β, IL-6, and tumor necrosis factor alpha (TNF-α) cytokines are multifunctional and are produced by a variety of cell types. All of these cytokines have been demonstrated to be involved in the complex process of inflamm-aging. Serum levels of inflammatory cytokines including IL-647,48 and TNF-α49 are significantly elevated in the elderly, whereas anti-inflammatory cytokine IL-1050 is decreased. Furthermore, it has been shown in vitro that as T cells undergo replicative senescence, the production of pro-inflammatory cytokines increases both IFN-γ and TNF-α.28 In vitro studies of human mononuclear cells have shown increased IL-1β, IL-6, IFN-γ, and TNF-α production.51 Inflamm-aging cytokine profiles measured in vitro likely reflect the dysfunctional activity of senescent cells in vivo.

Elevated levels of these inflammatory cytokines, in particular TNF-α and IL-6, have been associated with morbidity and predict mortality in the elderly.49,52 Moreover, chronic inflammation is a characteristic part of the pathological processes of age-related diseases such as atherosclerosis, osteoarthritis, Alzheimer’s, Parkinson’s, osteoporosis, and type 2 diabetes.58 However, it still remains controversial whether inflammatory mediators have primary causal relationship or simply contribute and/or aggravate the pathologies of these age-related diseases or may be the consequence of age-related diseases.18,49,52,59

More recently, studies have shown that aged horses, like humans, show evidence of inflamm-aging that may contribute to the development of age-associated conditions such as arthritis, cancer, diabetes, osteoporosis, dementia, vascular diseases, obesity, and metabolic syndrome. More specifically, it has been shown that old horses have significantly higher levels of inflammatory cytokines (IL-1β, IL-15, IL-18, and TNF-α) in peripheral whole blood when compared with younger horses.60 In addition, Adams and colleagues60 found that old horses compared with young horses have increased inflammatory cytokine (TNF-α and IFN-γ) production from peripheral blood mononuclear cells, and the frequency of these cells in circulation are also increased. Moreover, it was found that obese old horses have even higher frequencies of lymphocytes and monocytes producing inflammatory cytokines (TNF-α and IFN-γ) compared with old thin horses.51 This may suggest that increased adiposity or obesity may contribute to the inflamm-aging process. Reduction of body weight and adiposity in these old horses significantly reduced the levels of lymphocyte and monocyte TNF-α and IFN-γ-positive-producing cells.61 In addition, serum levels of TNF-α were significantly reduced when body weight and adiposity decreased.61

This age-related dysregulation of pro-inflammatory cytokine production has not only been shown to occur in the peripheral blood samples but recently this inflamm-aging phenomenon has been shown to occur in the lung. Bronchoalveolar-lavage cells were collected from clinically healthy horses and production of inflammation was measured.62 The frequency of IFN-γ-producing lymphocytes in both bronchoalveolar lavage and peripheral blood mononuclear cells (PBMCs) from old horses was significantly increased compared with the young horses.62
This age-associated increase of pro-inflammatory cytokine production may be a cofactor for the pathogenesis of equine airway diseases. Furthermore, when old horses were subjected to an influenza challenge, they showed an exacerbated increased production of pro-inflammatory cytokines post-infection, which is consistent with the concept of inflamm-aging, an enhanced pro-inflammatory state observed in the elderly.15,18 Alongside the concept that aged horses show evidence of a pro-inflammatory state that may contribute to development of age-associated diseases, it has been shown that horses with PPID have changes in the expression of pro-inflammatory or chemokines, which may influence the ability of these horses to respond to bacterial pathogens.63 Thus, it is critical to further characterize and understand the cause of inflamm-aging in old horses and what exactly does this inflamm-aging phenomenon mean or tell us about how well or not the horse is aging.

This chronic inflammatory activity is not only associated with age-related diseases but is commonly proposed as a promoter of biological aging in general, and of leukocyte telomere shortening in particular. Leukocyte telomere length is an emerging marker of biological age.64 We have shown that there is an age-associated loss of telomeres in horse peripheral blood mononuclear cells and this is not only related to their proliferation potential but also to the increased pro-inflammatory cytokine production.44 Thus, older horses with high levels of inflammatory activity may be at increased risk for accelerated leukocyte telomere shortening, and those with short telomeres may suffer the consequences of increased risk for diseases with an inflammatory etiology.

Immunosenescence and Vaccination

All of these changes of inflamm-aging and immunosenescence likely contribute to reduced responsiveness to vaccination and infectious agents.17,28,65 Studies have examined immune responses to influenza vaccination to evaluate the secondary or anamnestic immune responses. These studies have shown that old horses compared with younger horses have a reduced humoral immune response to inactivated influenza virus vaccines.24,66,67 In contrast with measuring an anamnestic response, one study has investigated antibody production following exposure to rabies antigen, which was used to measure primary immune response. This was possible because the study was performed on Prince Edward Island, which is rabies free; thus, most horses are not vaccinated against rabies.66 A primary immune response occurs when an animal is exposed to an antigen for the first time. This primary response involves the process of recruiting naive lymphocytes, which become activated, and must be able to proliferate and finally create memory T and B cells. These memory cells will play a role in providing protection from subsequent challenges by the same antigen. Interestingly, results of this study demonstrated that aged horses mounted antibody responses similar to younger horses.66 However, it was found that aged horses may have greater difficulty maintaining an adequate antibody titer after a single dose of rabies vaccine compared with younger horses.66 Perhaps alternative vaccination approaches may prove more efficacious in aged horses. Thus, a study measuring both antibody and cell-mediated immune responses of aged horses to a canarypox-recombinant virus vector expressing the haemagglutinin antigen of influenza was undertaken.15 The vaccine was effective at inducing both antibody and cell-mediated immune responses of young naïve horses. Although the old horses had prior evidence of pre-existing immunity to influenza, their antibody responses were enhanced only slightly by the vaccine. The old horses’ cell-mediated immune responses post vaccine were evident but not statistically significant over time.15 Although all of these vaccine studies measured immune responses of aged horses to vaccination, no studies had investigated vaccine efficacy except for the later study by Adams and colleagues.15 Adams and colleagues demonstrated that aged horses remain susceptible to infection with equine influenza virus despite the presence of circulating antibodies and cell-mediated immune responses to equine influenza. Although the vaccine induced significant antibody responses in aged horses but not cell-mediated immune responses, the canarypox-vectorized influenza vaccine did provide protection from clinical disease in these aged horses. Following this study and described below, we conducted an experimental trial comparing the immune responses of aged horses to modified live vaccine technology compared with inactivated or killed vaccine technology given that live vaccines are thought to better mimic a natural infection and thus inducing the best immune response post vaccination. Further, and described below, we conducted a study to determine whether equine PPID affects immune responses to vaccination.

Nutrition in Enhancing Immunity in the Old Horse

Nutritional immunology is a new field of study, in which nutrition is used as a modifiable factor in affecting immune function, in particular to delay/reverse immunosenescence and to improve the aged resistance to infection. Further, nutritional interventions are practical, cost-effective approaches to mitigating this age-related breakdown in immune function. Natural dietary compounds found in a variety of plants, roots, fruits, vegetables, nuts, and seeds are promising candidates in helping to combat the effects of an aging immune system. They possess broad biological activities: anti-oxidative, anti-inflammatory, detoxification, regulating signaling pathway, modulation of enzyme activities, and improving immune responses to vaccination.68
Given that old horses have increased levels of inflammation and long-term use of nonsteroidal anti-inflammatory drugs (NSAIDs) such as flunixin meglumine and phenylbutazone can pose health problems, there is a lot of interest in nutritional interventions to counteract this inflam-aging process. Recently, we compared flavonoid and polyphenolic compounds with main dietary sources of blueberries, red grapes, turmeric, and green or black tea (pterostilbene, hydroxypterostilbene, resveratrol, curcuminoids, quercetin), to NSAIDs on equine cytokine production in vitro, as a preliminary to in vivo research. We isolated white blood cells from aged horses and incubated them overnight with each compound or NSAID at multiple concentrations and measured inflammation production when cells were stimulated. At varying doses, each of the compounds and NSAIDs (curcuminoids [20 μM], hydroxypterostilbene [40 μM], pterostilbene [80 μM], quercetin [160 μM], resveratrol [160 μM], banamine [40 μM], and bute [≥ 320 μM]), significantly reduced inflammation. Interestingly, curcuminoids seem to have the potential to outperform NSAIDs.

Few studies have been conducted to better understand what effect nutrition may have on modulating or improving immune responses of the aged horse. Petersson and colleagues conducted a study to examine the effect of vitamin E supplementation on immune function and response to vaccination in older horses. Vitamin E is considered one of the most effective nutrients to enhance immune function. Vitamin E, a very effective chain-breaking, lipid-soluble antioxidant present in the membrane of all cells, and is particularly enriched in immune cells, which protects them from oxidative damage. Vitamin E supplementation in the aged, has been shown to enhance immune response, which is possibly associated with increased resistance against several pathogens. In the study conducted by Petersson and colleagues, horses were supplemented with 15 times the Nutrient Requirements of Horses (2007) daily for 16 weeks and immune responses measured throughout. The results of this study showed that vitamin E supplementation improved the bacterial killing ability of monocytes and neutrophils. Furthermore, humoral immune responses were enhanced, as evidenced by increases in particular subclasses of IgG concentrations in response to vaccination in the vitamin E-supplemented aged horses.

Prebiotics and probiotics, generally categorized as functional foods, are increasingly being recognized as effective, immune-modulating nutritional factors. These functional foods are thought to modulate the immune system at the mucosal surfaces throughout the gastrointestinal tract. In fact, several studies have shown that supplementation with either of these functional foods can enhance both the innate and adaptive arms of the immune system in aged subjects. Thus, we recently conducted a series of studies which are discussed below in collaboration with Purina Animal Nutrition, in which old horses were fed a diet feed® with and without a proprietary, prebiotic additive for a period of time, followed by challenging the immune response.

2. Methods

Comparison of Immune Responses in Aged Horses Given Commercially Available Live or Inactivated Equine Influenza Vaccines

Here, we conducted an experimental trial comparing the immune responses of aged horses to modified live vaccine technology compared with inactivated or killed vaccine technology given that live vaccines are thought to better mimic a natural infection and thus induce the best immune response post vaccination. The aim of this study was to compare the immune responses of aged horses given two doses of commercially available live or inactivated influenza vaccine. Twenty-six old horses (≥20 y) were included in this study, all of which had pre-existing hemagglutination-inhibition (HI) antibody titers. Treatment groups were stratified based on hemagglutination-inhibition (HI) titers: 1) (n = 7) inactivated EIV vaccine (OH/03 and KY/95 and NM/93), 2) (n = 7) inactivated EIV vaccine (KY/97), 3) (n = 7) live recombinant vectored EIV vaccine (KY/94 and NM/93), and 4) (n = 6) nonvaccinate controls. Serum samples were collected prior to (day 0) and post vaccination (days 7 and 14). Fourteen days (day 28) after the first vaccination, all horses received a second vaccination, and serum collected on days 35 and 42. Antibody responses were measured by HI and single-radial hemolysis against the homologous virus for each vaccine and against a heterologous virus (KY/02). Following this study and given the fact that PPID affects a large number of older horses, we wanted to answer the below question.

Does Equine PPID Affect Immune Responses to Vaccination?

During the past decade the aged horse population has expanded significantly with 20–30% of the equine population composed of geriatric horses (≥20 y), and of these horses approximately 30% are affected by PPID, a progressive and debilitating endocrine disease. Thus, we recently conducted a study comparing antibody responses to a (combination) multi-valent vaccine in non-PPID, age-matched control horses to PPID horses (testing either positive using the dexamethasone suppression test [DST] and/or testing positive using the thyrotropin releasing hormone [TRH]-stimulation test). A total of 33 aged horses of mixed sex and breed were used in this study. All horses were prescreened to determine EIV antibody titers and PPID status based on responses to a DST and a TRH-stimulation test. Further, all horses were assigned a numeric value for severity of clinical signs (hair coat, muscle condition, etc.) of PPID by two blinded DVMs via an
established scoring system. Non-PPID horses were characterized by cortisol levels (≤0.2 ug/dL) at 19 hours post-DST and adrenocorticotropic hormone (ACTH) levels (≤35 pg/mL) pre-TRH stimulation and ACTH levels (≥110 pg/mL) at 10 minutes post-TRH-stimulation test. Horses with PPID were further characterized by either double positive (DP) (DST no suppression and pre-TRH ACTH [≥35 pg/mL] and 10 minutes post-TRH [≥110 pg/mL] or single positive (SP) (DST suppression but pre-TRH ACTH [≥35 pg/mL] and 10 minutes post TRH [≥110 pg/mL]) responders. Treatment groups were randomly blocked according to these measures, along with age, to the following vaccinate groups: Group 1: Non-PPID horses, vaccinated IM with a combination (multi-valent) vaccine (n = 12); Group 2: Non-PPID controls, receiving a sterile saline vaccination (n = 3); Group 3: PPID horses (DP, n = 7; SP, n = 7) vaccinated; and Group 4: (n = 6) PPID horses receiving sterile saline vaccine (DP, n = 2; SP, n = 2). Peripheral blood for antibody titer measurements to EIV, EHV-1, and WNV were collected prior to the first vaccination (week 0) and again at weeks 2 and 4 post vaccination. A second multi-valent vaccine or saline control was given at week 4 and blood collected at weeks 6 and 8 post vaccination.

Parasite Control and the Aged Horse
As part of the care and management of horses, parasite control is of importance. Given the changes in the immune system with age, it remains to be determined the effect of age on levels of strongyle fecal egg counts and the possible inflammatory responses to anthelmintic treatment in geriatric horses. Thus, we recently conducted an experiment to evaluate whether aged horses demonstrate statistically higher fecal egg counts (FEC) compared with middle-age adult horses and to investigate systemic expression of pro-inflammatory cytokines in old and middle-age horses treated with moxidectin compared with horses treated with pyrantel pamoate.72 Old horses (n = 21) and middle-age horses (n = 19) were blocked by levels of inflammation and randomly allocated to one of the following treatment groups: Group 1 (n = 8), old treated with moxidectin gel; Group 2 (n = 9), old treated with pyrantel pamoate paste; Group 3 (n = 4), old receiving no treatment; Group 4 (n = 8), middle-age treated with moxidectin gel; Group 5 (n = 7), middle-age treated with pyrantel pamoate paste; and Group 6 (n = 4) middle-age receiving no treatment. Fecal samples were collected on day 0 and again 14 days after treatment to determine FECs and presence of Strongylus vulgaris by polymerase chain reaction (PCR). Peripheral blood was also collected on day 0 and again at days 3, 5, and 14 after deworming for inflammatory cytokine analysis, along with routine hematological analyses.

What Does Inflamm-Aging Mean for the Aged Horse?
PPID is an endocrinopathy commonly associated with aging in the equine population. Inflamm-aging (systemic low-grade chronic inflammation) also occurs with aging. Little is currently known about whether the inflammation or nutritional status of geriatric horses may be associated with the occurrence of PPID. Sarcopenia frequently accompanies PPID; thus, muscle mass is also of interest. To determine whether inflamm-aging, nutritional status, muscle mass, and PPID status may be correlated, various measures of these parameters were compared in geriatric horses.73 Forty-three old horses (mean 24.4 ± 3.0 y) were used to measure immune, endocrine, muscle, fatty acid, vitamin, and mineral parameters. PBMCs were isolated from heparinized blood, purified, antibody-stained intracellularly, and analyzed via flow cytometry to determine lymphocyte production of interferon-γ (IFNγ) and TNF-α. Ribonucleic acid (RNA) was also isolated from PBMCs and underwent PCRs to determine expression of various inflammatory cytokines. Serum IL-6, C-reactive protein, and TNF-α levels were determined via enzyme-linked immunosorbent assays (ELISAs). Serum vitamin, fatty acid, and mineral levels were also measured. Muscle and fat mass were determined via ultrasound; muscle scores were also assigned (0–3). Thyrotropin-releasing hormone (TRH) stimulation was performed to determine PPID status, in which ACTH levels were measured in plasma pre and 10 minutes post (T-10) intravenous administration of TRH (1 mg/mL saline per horse). Pearson correlation testing was performed to determine correlations between various parameters.

Nutrition in Enhancing Immunity in the Old Horse
The objective of the first study was to determine whether feeding of a proprietary prebiotic additive or a source of omega-3 fatty acids (marine-derived DHA) would improve immune response to vaccination and decrease inflamm-aging in geriatric horses.74 Forty horses (20–33 y) of mixed breed and sex were pre-screened for and blocked to one of four treatment groups by inflammatory status and pre-existing antibody titers to influenza: traditional grain mix (TGM; n = 10), C (control; n = 10), control-docosahexaenoic acid (CDHA) (control + docosahexaenoic acid (DHA); n = 10), and control prebiotic (CA) (control + prebiotic6; n = 10). Horses were fed isocaloric diets with respective treatments (adjusted to maintain body condition) individually twice daily for 161 days and were allowed free-choice access to mixed grass hay while housed on pasture. Horses were weighed, assigned BCS, and blood samples were taken throughout the study to measure inflammatory cytokines TNF-α, IL-6, and IFN-γ using RT-PCR, intracellular staining/flow cytometry (IF/FC), and ELISA techniques. On day 56, all horses received two separate vaccinations, an equine influenza vaccine and a novel antigen (OVA).
OVA vaccination was boosted on day 70. Prior to and 2 weeks post-vaccination, blood samples were collected to determine influenza and OVA-specific immune responses. A randomized factorial split-plot design was used to determine the effect of treatment, time, and treatment × time interactions with significance level of \( P < .05 \).

The objective of the second study was to determine the effect of feeding different levels of prebiotic supplementation on immune function in aged horses. Thirty-two aged (≥ 20 y) horses of mixed sex and breed were assigned to one of four treatment groups: control diet\(^g\) (ES; \( n = 8 \)), control diet\(^g\) + prebiotic \( 1^g \times (ESA1; n = 8) \), control diet\(^g\) + prebiotic \( 2^g \times (ESA2; n = 8) \), and control diet\(^g\) + prebiotic \( 3^g \times (ESA3; n = 8) \). Horses were fed isocaloric diets with respective treatments (adjusted to maintain body condition) individually twice daily for 86 days and were allowed free-choice access to mixed grass hay while housed on pasture. Horses were weighed, assigned BCS, and blood samples were taken throughout the study on days 0, 35, 56, and 86 to measure inflammatory cytokines TNF-\(\alpha\), IL-6, and IFN-\(\gamma\) using RT-PCR, IS/FC, and ELISA techniques. All horses were vaccinated with a novel antigen (KLH) on days 28 and 42 and with an equine influenza vaccine on day 42. Prior to vaccination and 2 weeks post-vaccination, blood samples were collected to determine influenza- and KLH-specific immune responses using an antigen-specific ELISA and a HI assay. Data was checked for normality and log transformed if necessary. A completely randomized factorial split-plot design was used to test the effect of treatment, time, age, sex, and treatment × time interaction. ANOVA was performed with mixed models and least-squares means compared with Fisher’s LSD with a significance level of \( P \leq .05 \) and trend of \( P \leq .10 \).

### 3. Results

#### Comparison of Immune Responses in Aged Horses Given Commercially Available Live or Inactivated Equine Influenza Vaccines

Prior to vaccination, there was no significant difference in HI or SRH antibody titers between all groups. Post-vaccination, there was a significant increase in both HI and SRH titers for all three vaccine groups (day 0 vs day 7; \( P < .05 \)) but no change when comparing day 7 vs day 14 results. We found that both inactivated vaccines induced a significantly (\( P < .05 \)) higher antibody response when compared with the recombinant vaccine. Administration of a second vaccine dose did not increase the antibody responses in any of the vaccine groups.

#### Does Equine PPID Affect Immune Responses to Vaccination?

Results suggested that all horses receiving vaccination responded significantly with an increase in EIV and EHV-1 antibody titers post vaccination. Further, results suggested that there was no significant difference in EIV antibody titers vaccinations between non-PPID and PPID horses, however, there were significant (\( P < .05 \)) differences in EHV-1 and WNV humoral immune responses among the PPID horses. Thus, vaccination in the face of PPID does have an effect on how these horses respond immunologically (Adams AA, et al., AAEP 2014). Further characterization of the duration of immunity and vaccine efficacy of PPID horses compared with non-PPID horses is warranted.

#### Parasite Control and the Aged Horse

Results of this study suggested that old horses have significantly higher FEC than the group of middle-aged adults.\(^{71}\) FECs declined significantly following anthelmintic treatment in both age groups of horses. Several of the measured inflammatory markers did exhibit pronounced differences between age groups, and this study provided evidence of higher expression of IFN-\(\gamma\), TNF-\(\alpha\), IL-6, and serum amyloid A (SAA) post deworming in the old horse group. In summary, this study provided evidence of different inflammatory and immunologic reactions to anthelmintic treatment in old horses. Moreover, the higher strongyle egg counts found in the old-horse group may have practical implications for parasite management routines implemented on farms with representation of this age group.

#### What Does Inflamm-Aging Mean for the Aged Horse?

Baseline ACTH and T-10 (\( R = 0.631; P < .001 \)) yielded a strongly significant relationship. Age and T-10 ACTH (\( R = 0.256; P = .0973 \)) exhibited a trend, whereas age and basal ACTH (\( R = 0.389; P = .0109 \)) were significantly correlated. ACTH was not significantly correlated with muscle, fatty acid, vitamin, or mineral measures. Inflammatory markers also did not seem to be correlated with ACTH; thus, PPID and inflamm-aging may not be associated. Age, however, exhibited a positive correlation with fatty acids C18:2n6c, C20:4n6c, and C24:1n9c, as well as with lymphocyte production of IFN-\(\gamma\) and TNF-\(\alpha\), and serum selenium and vitamin E (\( P < .05 \)). Age showed a negative correlation with fatty acids C16:0 and C20:1n9c, fat-free mass, fat weight, and muscle score (\( P < .05 \)). The correlation of age with various measured parameters suggests that age plays a role in regulating inflammatory and metabolic function of the horse.\(^{72}\)
Nutrition in Enhancing Immunity in the Old Horse

Results of the first study showed that all horses gained weight and increased BCS over time ($P < .05$). TNF-α (RT-PCR and ELISA) was lower in CA than C at the end of the study on days 105, 133, and 161 ($P < .05$). IL-6 (ELISA) decreased in TGM over time ($P < .05$). IFN-γ (RT-PCR) was lower in CA and C than TGM at day 161 ($P < .05$), and overall, IFN-γ (IS/FC) increased over time in TGM, C, and CDHA, but not in CA ($P < .05$). There were no effects of diet on vaccination response, but there was a negative correlation between OVA titer and age ($R = -0.32; P < .05$). Overall, horses receiving the diet containing the prebiotic additive exhibited a lower inflamm-aging status post-treatment when compared with horses receiving the other three diets. Thus, the addition of a prebiotic may help protect against the negative effects of aging on immune response in old horses.

Results of the second study showed that all horses slightly lost weight but increased in BCS over time. Levels of the key inflammatory cytokines TNF-α and IFN-γ increased in ES but did not change in ESA1, ESA2, or ESA3 ($P < .05$). IL-6 decreased only in ESA2 over time ($P < .05$). Influenza antibody titers were higher in ESA2 than ES and ESA3 at day 56 ($P < .05$), and the increase in influenza antibody titers was greatest in ESA1 ($P < .05$). There were no effects of diet on KLH-specific vaccination response.

4. Discussion

Taken together, these studies show that although aged horses have pre-existing immune responses to pathogens, these levels may not be sufficient enough to provide the animal protection in the face of an infectious challenge. Thus, vaccination is important to maintain a protective level of immunity and by preserving memory responses. Thus, it is critical to ensure that clients keep their old horses up to date with the core vaccines, provided by the American Association of Equine Practitioners (AAEP). We do see some changes in how some horses with PPID respond to vaccinations. Thus, if clients have older, more at-risk horses such as horses with PPID, and perhaps older horses that are still showing and traveling, it might mean potentially vaccinating these horse more often, perhaps boosting that horse with West Nile vaccine at 6 months rather than just annually, for instance, especially in a region with a long mosquito season. Regardless, keep older horses up to date with annual core-based vaccinations if they are not traveling, consider giving risk-based vaccinations, and perhaps consider boosting every 6 months.

It is important to consider targeted nutrition to help support the immune response. Results of this study showed that old horses supplemented with the prebiotic yeast had reduced levels of inflammation and enhanced humoral immune responses after vaccination compared with horses not receiving the supplement. Thus, nutritional intervention regimens can improve the immune function of the aged horse. Moreover, an appropriate nutritional program is important to implement based on endocrine status, in particular screen for insulin resistance to help establish the nutritional program of these older horses.

Given the changes in the immune system with age in horses and the fact that the immune system is important in regulating tolerance to parasites, it is critical to implement FECs as part of routine or annual geriatric horse healthcare. Results from our studies suggested that older horses have significantly higher FEC than middle-age adults. FECs declined significantly after anthelmintic treatment in both age groups of horses. Thus, the higher FECs found in the old horse group may have practical implications for parasite management routines on farms with representation of this age group, however, perform FECs and FEC reduction tests to guide the parasite control with aged horses. Do not assume.

Lastly, we know that inflamm-aging (systemic low-grade chronic inflammation) also occurs with aging in horses; however, more research is warranted to understand what this means for geriatric horse healthcare. Ongoing studies are being conducted to understand whether inflamm-aging has any relationships with age-related conditions in the horse including osteoarthritis, insulin resistance, etc. with the goal being to offer clients additional biomarkers to allow for additional annual screening to determine whether the horse is aging healthy or not, so stay tuned. The field of anti-aging research is growing exponentially in human medicine, and we expect this area of research and practice to grow in equine medicine.

Regardless, not only is it critical to implement annual or bi-annual vaccination and FEC schedules for geriatric horses, it is also important to consider adding the following into your Spring and Fall wellness plan for aging horses: dental exams, endocrine screening for PPID and insulin resistance, body condition evaluation, weight tapes, front and side profile photos, nutritional evaluation and consultations, lameness evaluations, lateral feet radiographs, hoof tests, and examinations. Moreover, it is important to consider offering some educational programs on senior horse healthcare to the owners of these older horses to engage interest in maintaining wellness plan programs for these horses in your practice.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
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How to Recognize, Evaluate, and Treat Patent Urachus

Pamela A. Wilkins, DVM, MS, PhD, DACVIM, DACVECC

1. Introduction

Patent urachus is a relatively common problem identified in foals during the neonatal period. The urachus is the extension of the urinary bladder of the fetus to the allantoic cavity, contained retroperitoneally within the umbilical cord between the two umbilical arteries, and is involved in the removal of nitrogenous wastes from the fetus. In humans the urachus is generally closed by 12 weeks of gestation and becomes the median ligament of the bladder, although it may very rarely be patent.1 The median ligament of the bladder serves to support the ventrally oriented and upright position of the bladder.

Species with epitheliochorial placentation and retention of both the allantoic cavity and contained fluids throughout gestation, such as the horse, will have an open and functional urachus until the time the umbilical cord separates at parturition, leaving both internal and external umbilical remnants.2,3 Although functional closure of the urachus occurs at this time, anatomic closure does not. The urinary bladder and associated internal umbilical remnant gradually retract from the body wall during the first several weeks of life, leaving the umbilical arteries to become the round ligaments of the bladder and the umbilical vein to become the Falciiform ligament of the liver and the urachus involutes. The supporting fold of the urachus present in prenatal life primarily involutes with the urachus following birth, but a small fold remains to become the median ligament of the bladder, attaching the ventral surface of bladder to the pelvic floor and the linea alba.4–6

Following birth the umbilical cord will naturally separate at a site located approximately 2–3 cm from the hairline, corresponding to narrowing of the umbilical arteries and vein.2,3 The external umbilical stump may display some variable patency for up to 24 hours as it dries out and involutes over a 3–7-day period. The umbilical stump should be completely healed by 3–4 weeks of age.3

Routine care of the umbilical stump has been well described. Dipping of the umbilical stump of newborn foals into a variety of disinfectant solutions two to three times daily following birth is common practice. Solutions used include 0.5% chlorhexidine and 1% povidone iodine.3 Use of dilute chlorhexidine solutions have been shown to significantly decrease the incidence of umbilical stalk infection and death in human infants and is most commonly recommended for foals.7,8 Care should also be used with application of silver nitrate, historically and still commonly used to promote urachal closure,
given that a necrotic focus can develop. Excessive drying caused by application of concentrated iodine solutions or silver nitrate causes bacterial trapping and tissue devitalization, providing a favorable environment for bacterial growth and promoting patency of the urachus.3,7

2. Recognition of Patent Urachus

Patent urachus is readily recognized when a foal is either observed to have a stream of urine originating from the umbilicus or it is noticed that the hair around the umbilicus is consistently wet. Regional urine scalding of the skin may be apparent if urine has been emanating from the urachus for a period of time and there may be local maceration of skin at the umbilicus or in regions of the ventral abdomen and medial hind limbs. Identification of urachal patency can be somewhat challenging in male foals that urinate into their prepuce, more common if the penile frenulum is still intact. In these cases, placing a flat hand perpendicular to midline and oriented vertically on the ventrum between the umbilicus and the prepuce will deflect the urine stream originating from the prepuce and allow direct visualization of any urine stream from the umbilicus.

3. Evaluation of Patent Urachus

History is an important component of evaluation for patent urachus. Patent urachus can develop shortly after birth or later in the first 7–14 days of life. Foals with patent urachus may present as otherwise healthy, showing early signs of infectious disease, or with prolonged recumbency due to another primary disease process. It is seldom a complaint of foals older than 2 weeks of age and the author has not recognized a case of patent urachus in a foal of weaning age. There are no studies directed fully at the evaluation of patent urachus as a single entity or following the fate of the urachus—and the internal umbilical remnant—sequentially during the first weeks and months of life in normal foals. If available, knowledge of the circumstances of parturition may be beneficial as may information related to periparturient problems such as dystocia or placental abnormalities.

The umbilical cord itself may contribute to patent urachus and other umbilical problems.2,3,9,10 An excessively long umbilical cord can be associated with umbilical cord torsion, predisposing to urachal compromise by causing obstruction of blood flow and obstruction to urine flow from the fetal urinary bladder to the allantoic cavity. Decreased cord length (<30 cm) predisposes to increased traction on the umbilical cord that can compromise the integrity of the urachus.

In addition to addressing questions of history and placental abnormalities, a thorough physical examination should be undertaken with particular attention paid to the umbilical remnant. Patent urachus is associated in many reports with infection with other umbilical structures and also with uroperitoneum secondary to failure of urachal integrity.11–15 Routine clinical pathology testing including CBC, plasma or serum chemistry, and assessment of adequacy of passive transfer of maternal immunity should be performed.

Ultrasonographic examination is an important diagnostic and monitoring tool in cases of patent urachus and examination of the umbilical remnant has been reviewed and extensively presented elsewhere. The presence of patent urachus in a neonatal foal suggests that the umbilical remnant is abnormal. It does not, however, suggest any specific abnormality. Causes of patent urachus can be categorized as follows:

Simple Patent Urachus
In these cases patency may be present immediately after birth or become apparent in the first few days of life in an otherwise-healthy and vigorous foal. This form of patent urachus generally resolves spontaneously as the foal becomes more active and micurates more frequently, applying tension to the internal umbilical remnant and encouraging closure of the urachus. Historically, the umbilical cord may have broken close to the foal or been cut or tied off close to the foal. These cases may also be observed in male foals urinating into their prepuce, resulting in a constantly wet macerated umbilical stump. In some cases the umbilical stump may have been treated often and vigorously, again resulting in a constantly wet umbilical stump. Paradoxically, use of silver nitrate or higher concentrations of iodine solutions can result in patent urachus secondary to excessive drying and subsequent necrosis of the umbilical stump.

Mechanical Patent Urachus
Patency of the functionally but not yet anatomically closed urachus may occur secondary to abdominal straining, such as seen with meconium retention/impaction or stranguria secondary to urachitis. Urachitis is commonly associated with urachal diverticulum, where the urachal portion closest to the bladder remains open, resulting in some urine pooling in the urachus.16,17 This condition is only recognized with an ultrasonographic examination of the internal umbilical remnant and can result in minor discomfort and straining following urination but generally requires no specific treatment and usually resolves within 1–3 days.

Infectious Patent Urachus
The urachus becomes patent associated with infection of structures of the internal umbilical remnant and generally manifests when a foal is several days to 1–2 weeks of age. Infection may remain clinically silent for a period of time but localized clinical signs of umbilical stump swelling, purulent discharge, heat and pain on palpation are compatible with umbilical infection. The umbilical stump...
should be evaluated daily for evidence of local infection although infection may not manifest externally. Inflammation, infection, and necrosis can become locally extensive. In these cases where infection has become locally extensive, or becomes systemic, clinical signs may include fever, depression, and poor suckling. It has been postulated that infection might ascend along the urachus to the urinary tract and facilitate bacteremia. Local urachal infection may also result in uroperitoneum due to formation of internal urachal defects associated with areas of necrosis; foals with urachal infection or trauma should be ultrasonographically evaluated frequently, even daily, for this complication. Development of uroperitoneum generally requires surgical intervention and correction by removal of the umbilical remnant once the foal is medically stable. Detailed discussion of uroperitoneum, including identification and treatment, is beyond the scope of this article.

Urachal Patency Associated With Critical Illness
Foals with critical illness—such as sepsis, neonatal maladjustment syndrome, prematurity—or with problems such as congenital severe flexural deformities may experience prolonged recumbency. Development of patent urachus is almost considered an expected problem in these cases by experienced clinicians. Its genesis is generally similar to simple patent urachus, with components of mechanical patent urachus, given that the ventrum of these foals are frequently damp, causing maceration of the umbilical stump, and they are not assuming a normal body position to urinate. Trauma secondary to recumbency may also result in early loss of the umbilical stump. These foals may not recognize a full bladder and the need to urinate, resulting in increased pressure on the urachus from the full bladder. This is a particular problem with critically ill male foals due to the resistance to passive urination presented by their long urethra. In the majority of these cases umbilical or urachal infection is not the primary cause.

4. Treatment of Patent Urachus
Many cases of simple patent urachus identified in otherwise-healthy and -active foals that are not associated with umbilical remnant infection do not require specific treatment and will resolve with time and activity, generally within 1–3 days following birth. Local treatment in these cases includes keeping the area clean and dry and the use of emollients to provide a moisture barrier to prevent urine scaling in wet affected areas. A similar approach should be considered in cases of mechanical patent urachus. In both instances broad-spectrum antimicrobial therapy may be considered, particularly antimicrobials that are concentrated in the urine such as trimethoprim-sulfa combination antimicrobial drugs. Antimicrobial drugs with potential for nephrotoxicity (aminoglycosides, oxytetracycline) should be avoided if possible in these cases. Ultrasonographic examination of the umbilical remnant should be undertaken and repeated frequently, daily if possible, to monitor for potential infection or development of uroperitoneum until the problem is resolved in all cases of patent urachus.

Mechanical patent urachus associated with urachal diverticula and urachitis will benefit from antimicrobial treatment with trimethoprim-sulfa combination antimicrobial drugs; stranguria can be alleviated by administration of phenazopyridine hydrochloride (pyridium, 2–3 mg/kg orally 2–4 times daily), an azo dye that serves as a urinary tract mucosal anesthetic agent. The dye will turn the urine orange and the urine will stain/dye anything it comes in contact with. This treatment alleviates symptoms but is not curative. Again, frequent (daily if possible) evaluation of the umbilical remnant using ultrasonographic examination should be performed. Mechanical patent urachus secondary to meconium impaction or other causes of abdominal straining may be treated similarly.

Patent urachus secondary to umbilical remnant infection will commonly respond to medical management, administration of broad-spectrum antimicrobial drugs, and close monitoring. A swab of the stump may be taken for bacterial culture and sensitivity testing but may be more representative of local contamination than the culprit. A blood culture may also be obtained but, again, might not be representative of the offending microbe(s). Empirical anti-microbial treatment should be started immediately following assessment with initial choices for treatment including a β-lactam and an aminoglycoside. Renal function should be closely monitored, at least every other day, if aminoglycoside treatment is chosen, with attention paid to the normally decreasing creatinine concentrations during the first 1–3 days of life. Alterations (increases) in renal indices such as creatinine and blood urea nitrogen (BUN) suggest that aminoglycoside treatment should be altered or abandoned. If progress is being made based on clinical and ultrasonographic assessment medical management may be continued. Should medical management fail to result in relatively rapid improvement (signs of improvement being repeated ultrasonographic examinations showing first lack of progression over 1–3 days then improvement and decreasing signs of infection/inflammation such as lack of fever and stabilizing or decreasing fibrinogen concentration over the following 2–3 d) surgical resection of the umbilical remnant should be considered. Uncontrolled or severe infections may rarely result in adhesion formation between abdominal contents and the infected internal umbilical remnant and should be considered a potential indication for surgical intervention if noted during ultrasonographic examination. Successful medical management might require 2–3 weeks of treatment but avoids the need for general anesthesia in a compromised foal.

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Treatment of patent urachus associated with critical illness or prolonged recumbency is similar to that of simple or mechanical patent urachus. Careful attention to umbilical stump hygiene is important in these cases. Foals affected by critical illness are generally receiving broad-spectrum antimicrobial treatment and adjustments to treatment based on the development of patent urachus are generally not necessary. As with other causes of patent urachus, frequent, generally daily, assessment of the internal umbilical remnant for progressive evidence of uncontrolled infection is paramount, as is monitoring for the development of uroperitoneum. Urachal patency generally resolves as the foal becomes more active, stands more frequently, and begins to urinate in a normal standing position without additional specific treatment.

5. Discussion

Patent urachus is not uncommon in neonatal foals and frequently resolves spontaneously or with limited specific treatment, including umbilical remnant hygiene. The use of silver nitrate or concentrated iodine solutions to cauterize the urachus is no longer recommended due to the potential for local necrosis supporting local bacterial infection of the area that could extend to the internal umbilical remnant. In cases where patent urachus is associated with internal umbilical remnant infection medical treatment is initially indicated and frequently successful. Surgical solutions should be reserved for cases in which medical management has either failed, evidenced by continued progression of infection based on ultrasonographic, clinical and clinical pathologic examinations, or has not resulted in sufficient progress toward resolution, particularly in critically ill foals in which general anesthesia might further compromise the foal.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References

Effects of 1% Ophthalmic Atropine Sulfate Solution on the Gastrointestinal Motility and Transit Time in Healthy Horses

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1. Introduction
Topical ophthalmic atropine sulfate (2 mg, in the eye, every 6 h) for 2 weeks significantly decreased the number of borborygmi and decreased intestinal transit time in normal, healthy, light-breed horses during the second week of treatment. Atropine sulfate administered to the eye and stall confinement might predispose horses to decreased gastrointestinal (GI) motility, slower transit time, and colic.

2. Discussion
Atropine sulfate, topically administered to the eye, is the treatment of choice to minimize pain and prevent complications leading to blindness. The purpose of this study was to determine the effects of topical atropine sulfate (1% ophthalmic solution) administered to the eye on GI motility and transit time in healthy adult horses. Six clinically healthy adult light-breed horses free from ocular disease were housed in stalls and acclimated to a diet of hay and grain for 2 weeks prior to starting the study. The study was performed as a 2 × 2 crossover design in which all horses either received saline (control) or atropine sulfate (1% ophthalmic solution, 2 mg, intraocular (IO), every 6 h) administered through a subpalpebral lavage system for 2 weeks. The horses underwent a 2-week washout between treatment periods. GI sounds were counted for 2 minutes four times daily and a clinical score (0–3) was recorded. Abdominal ultrasound was performed on days 6 and 13 to assess contractile motility. The percentage of colored beads collected 96 h after administered via nasogastric tube on days 4 and 11 was used to evaluate progressive motility. Two of 6 atropine-treated horses showed clinical signs of colic. The total number of borborygmi in 2 min was significantly decreased in the atropine-
treated horses on days 9 through 14, compared with control horses (6.84 ± 1.67 and 8.68 ± 1.1, respectively). In addition, during the second week, atropine-treated horses passed fewer beads over 96 h compared with controls (53.5 ± 28.11 and 71.8 ± 25.45%, respectively). The number of intestinal contractions, recorded during ultrasound examination, was not different. Horses treated with topical ocular atropine sulfate (2 mg, every 6 h) for 2 weeks showed decreased borborygmi and delayed transit time by the second week of treatment. Atropine sulfate administered to the eye and stall confinement might predispose horses to decreased GI motility, transit time, and colic.

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The Authors declare no conflicts of interest.

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Cumulative Antimicrobial Susceptibility of Bacteria Isolated From Foals With Sepsis: 1990–2015

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Amikacin/ampicillin is one of the most effective antimicrobial drug combinations for empirical treatment of foals with sepsis. Authors’ addresses: Faculty of Veterinary Medicine, Utrecht University, 3584 CM, Utrecht, The Netherlands (Theelen); School of Veterinary Medicine, University of California—Davis, Davis, CA 95616 (Wilson, Byrne, Edman, Magdesian); e-mail: m.j.p.theelen@uu.nl. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Foal sepsis is rapidly progressive and requires immediate antimicrobial therapy. The objective of this study was to provide cumulative susceptibility data on a patient level to direct clinicians with empirical antimicrobial treatment.

2. Materials and Methods
Foals <30 days of age with sepsis, confirmed by isolation of bacteria from blood cultures or protected sites collected on admission, were included. Susceptibility testing was performed using the broth microdilutiona procedure. Statistical analysis: Fisher’s exact test.

3. Results
In total, 213 foals and 306 bacterial isolates were included. The percentages of foals from which all bacteria isolated at hospital admission were susceptible to selected antimicrobial drugs were: amikacin (63.4%), amikacin/penicillin (88.6%), amikacin/ampicillin (91.5%), gentamicin (62.0%), gentamicin/penicillin (82.0%), gentamicin/ampicillin (83.6%), ceftiofur (86.3%), ceftiofur/amikacin (89.6%), ceftizoxime (89.7%), chloramphenicol (81.6%), enrofloxacin (82.9%), imipenem (92.6%), and trimethoprim/sulfamethoxazole (59.6%). Survival of foals from which all bacteria were susceptible to the initial antimicrobial treatment was 65%. If one or more isolates were resistant, the rate of survival was significantly lower; 42% (P < .0416).

4. Discussion
Amikacin/ampicillin remains one of the most effective antimicrobial drug combinations to treat foals with sepsis and should be used as initial treatment, assuming normal renal function, while awaiting bacteriological culture and susceptibility results. Critically important antimicrobials for humans (e.g. imipenem) should not be used routinely in foals.
Survival of foals with sepsis increases if appropriate antimicrobial regimen is initiated.

Footnote

*Sensititre, ThermoFisher Scientific, Trek Diagnostic Systems, Oakwood Village, OH 44131.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Authors declare no conflicts of interest.

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Thrombocytopenia in Neonatal Equids

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Thrombocytopenia is associated with decreased survival in neonatal foals. Infectious and alloimmune disorders are common in these foals. Authors’ addresses: Department of Clinical Sciences, Veterinary Teaching Hospital, Colorado State University, Fort Collins, CO 80523 (Swain); Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California–Davis, Davis, CA 95616 (Magdesian); e-mail: elsbeth.swain@colostate.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Thrombocytopenia is not well studied in foals. The hypothesis was that thrombocytopenia is associated with decreased survival.

2. Materials and Methods
This was a retrospective review. The medical database at the Veterinary Medical Teaching Hospital, University of California–Davis was searched to identify foals age ≤14 d with thrombocytopenia (1998–2015). Case foals were designated into four groups based on severity of thrombocytopenia: (Group 1, 80,000–99,999/μL; Group 2, 50,000–79,999/μL; Group 3, 20,000–49,999/μL; Group 4, <20,000/μL). Foals admitted just before and after each case foal were selected as controls. Mortality rates were compared using Fisher’s exact test.

3. Results
A total of 133 foals with thrombocytopenia were identified out of 1414 admitted foals (9.4%). Among thrombocytopenic foals, 86/133 (64.7%) survived compared with 229/266 (86.1%) of controls. The mortality rate in thrombocytopenic foals was higher than in controls (P < .0001; OR, 3.18 [2.06–5.56]). Within thrombocytopenic foals, mortality rates were 26.2, 48.9, 46.2, and 16.7%, respectively in Groups 1–4. Group 2 foals had a higher mortality rate (P = .049), whereas Group 4 foals had a lower mortality rate (P = .037). This was likely associated with the prevalence of diagnoses among groups, given that more Group 4 foals had suspected alloimmune thrombocytopenia and more Group 2 foals had sepsis. Infectious diseases were common in thrombocytopenic foals (61.7%), including septicemia, gastrointestinal pathogens, equine herpesvirus-1, and Tyzzer’s disease. Alloimmune thrombocytopenia was suspected in 9.8%.

4. Discussion
Thrombocytopenia is common in hospitalized foals and is associated with increased mortality. Infectious and alloimmune disorders were common.

Acknowledgments
The study was supported by the Roberta A. and Carla Henry Endowed Chair in Emergency Medicine and Critical Care.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Systemic Inflammation Increases Synovial Serum Amyloid A Concentrations to Values Similar to Septic Arthritis

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Caution should be taken if using serum amyloid A (SAA) in synovial fluid for diagnosing horses with septic joints as a systemic inflammatory response will increase SAA in joints. Authors’ addresses: Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK S7N 5B4, Canada (Bracamonte, Waldner); School of Veterinary Science, University of Liverpool, Neston CH64 7TE, United Kingdom (Rubio-Martínez); e-mail: jlb923@mail.usask.ca. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Serum amyloid A (SAA) in synovial fluid has shown to increase in horses with septic arthritis. The objective of this study was to evaluate SAA in joints after inducing systemic inflammation using a laminitis-model. The second objective was to compare SAA in synovial fluid of horses with induced systemic inflammation to SAA from horses with naturally occurring septic arthritis.

2. Materials and Methods
Systemic inflammation was induced in six adult horses using a laminitis oligofructose model. Synovial fluid–SAA concentration of middle carpal and tarsocrural joints was determined at 0, 24, and 48 hours. Systemic-SAA concentration was determined at the same time points.

Synovial fluid–SAA concentration was compared between three groups of horses: Group 1 (control), Group 2 (systemic-inflammation), and Group 3 (septic arthritis). Data were analyzed by non-parametric statistics and significance set at $P < .05$.

3. Results
Systemic-SAA concentration was increased from baseline at 24 and 48 hours ($P < .0001$). Synovial fluid–SAA concentration significantly increased from baseline at 48 hours ($P < .0001$). There was no significant difference in synovial fluid–SAA concentration between horses with systemic inflammation and horses with septic arthritis ($P = .268$).

4. Discussion
Synovial fluid–SAA significantly increased in joints after inducing systemic inflammation at 48 hours. SAA in synovial fluid of horses with systemic inflammation had values comparable to those of horses with septic arthritis.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Funding Source
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Meropenem Synovial Fluid Concentrations After Intravenous Regional Limb Perfusion in Standing Horses

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Meropenem achieves clinically significant synovial fluid concentrations via intravenous regional limb perfusion. Authors’ address: Department of Clinical Sciences, College of Veterinary Medicine, Mississippi State University, Mississippi State, MS 39762; e-mail: rfontenot@cvm.msstate.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Intravenous regional limb perfusion (IVRLP) is an important treatment for synovial infections given that it achieves high local concentrations of antimicrobials. Meropenem, a carbapenem-class drug, is a time-dependent, broad-spectrum, bactericidal drug that has minimal reported resistance. The objectives of this study were to determine the synovial fluid concentrations of meropenem following IVRLP and to evaluate clinical adverse effects (e.g., lameness, injection site swelling).

2. Materials and Methods
Ten healthy horses received 500 mg of meropenem diluted in 20 mL of saline via forelimb IVRLP. Radiocarpal joint synovial fluid and serum were collected at 0, 0.08, 0.25, 0.5, 1, 2, 4, 6, 8, 12, and 18 h following IVRLP. Meropenem concentrations were determined using a microbiological bioassay.

3. Results
Mean time to peak synovial fluid concentrations was 0.5 h post IVRLP. Synovial fluid concentrations were variable with a mean of 23.47 mcg/mL (range, 0.77–75.46 mcg/mL). The mean time above 1 mcg/mL, the minimum inhibitory concentration (MIC) breakpoint for most pathogens, was 4.3 h. The mean peak plasma meropenem concentration was 1.72 mcg/mL (range, 0–2.85 mcg/mL). Meropenem was well tolerated with only mild swelling at the injection site in some horses.

4. Discussion
Meropenem is a novel antimicrobial for use in IVRLP. It achieves clinically significant synovial fluid concentrations above the MIC for common equine pathogens for at least 4 hours. Meropenem IVRLP is a safe, well-tolerated, therapeutic in horses that could be considered where resistance is an issue and other antibiotics have failed.
Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Funding Source
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Evaluating Seasonal Influences on Hormone Responses to a Diagnostic Test (Thyrotropin-Releasing Hormone Stimulation) Advocated for Early Diagnosis of Pituitary Pars Intermedia Dysfunction

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Both season and month significantly affect not only basal adrenocorticotropic hormone (ACTH) concentrations but ACTH responses at 10 and 30 minutes post thyrotropin-releasing hormone (TRH) stimulation and therefore should be considered when diagnosing pituitary pars intermedia dysfunction (PPID). Authors’ addresses: Gluck Equine Research Center, Department of Veterinary Science (Adams, Siard, Reedy, Barker, Elzinga, Cesar, Lawson, Tucker, Mulholland, Horohov); Department of Animal and Food Sciences (Urschel), University of Kentucky, Lexington, KY 40506; College of Veterinary Medicine, Washington State University, Pullman, WA 99163 (Ganz); The Animal Health Trust, Newmarket CB8 7UU, United Kingdom (Ireland); e-mail: amanda.adams@uky.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Horses with early pituitary pars intermedia dysfunction (PPID) may fail to test positive using basal endocrine diagnostic tests. Thus, the thyrotropin-releasing hormone (TRH) stimulation test is currently recommended where early PPID is suspected. Effects of season on the hormone responses to this dynamic test have not been fully evaluated in similarly managed groups of non-PPID, subclinical, and clinical PPID horses over a 12-month period.

2. Materials and Methods
The TRH stimulation test (T0, T10, and T30 min blood collections) and clinical evaluations were performed each month for a 12-month period using the same group of horses, under the same management, characterized as non-PPID (n = 17), subclinical PPID (no hirsutism and
one abnormal endocrine test) (n = 21), and clinical PPID (hirsutism and two or more abnormal endocrine tests) (n = 25). Ethylenediaminetetraacetic acid (EDTA) plasma adrenocorticotropic hormone (ACTH) was measured by Cornell.

3. Results and Discussion
Within non-PPID, subclinical PPID, and clinical PPID groups, repeated measures (RM) ANOVAs demonstrated basal, T10, and T30 ACTH values all varied significantly between months (P < .001). Two-way RM ANOVA demonstrated basal, T10, and T30 ACTH values all varied significantly with both PPID status and season (P < .001). Youden indices were used to determine seasonal and monthly cutoff values for basal, T10, and T30 ACTH concentrations, which should be considered when diagnosing PPID.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Funding Source
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How to Perform Standing Sinoscopy in Horses

Canaan Whitfield-Cargile, DVM, DACVS

Sinoscopy performed under standing sedation allows any practitioner with access to a flexible endoscope (or rigid arthroscope) the ability to easily visualize the interior of the sinuses in order to make diagnoses and remove any number of abnormal structures including inspissated pus, paranasal sinus cysts, or infected sinus lining. Author’s address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843-4475; e-mail: cwhitfield@cvm.tamu.edu. © 2016 AAEP.

1. Introduction
Nasal discharge is one of the most common presenting complaints encountered in equine practice. Although there are many possible causes of nasal discharge one of the most frequent causes is disease of the paranasal sinuses. These can include anything from primary bacterial sinusitis to sinus cysts, sinusitis secondary to dental disease, neoplasia, or inspissated pus within the sinuses due to longstanding infection. The vast majority of these are diagnosed based on clinical signs and radiographic findings, and treatment most often consists of systemic antibiotics with or without sinus lavage via sinus trephination. Horses that fail to respond to this approach are frequently referred to a tertiary-care facility for further diagnostics and treatment. Diagnostics and treatment at the referral center can include a host of advanced imaging modalities and surgical intervention. Endoscopic examination of the equine paranasal sinus cavity performed with a flexible endoscope in the standing horse has been described previously.1,2 This technique is rapidly gaining popularity at academic teaching hospitals and specialty private practices. In our experience, however, this technique is not widely used among general practitioners although the majority of general practitioners have the necessary equipment (flexible endoscope) to perform this procedure. Given the simplicity of this procedure and the fact that this procedure could enable the general practitioner to more accurately diagnose and treat paranasal sinus disease of the horse, we believe that this technique could be more widely adopted among general practitioners to improve their ability to appropriately diagnose and treat a host of sinus disorders in horses. Therefore the objectives of this “how to” are to 1) demonstrate to general practitioners the simplicity of this procedure, and 2) discuss the indications and advantages of this technique over other more traditional approaches. We believe this information will equip the equine practitioner with an additional tool in their repertoire to successfully manage a number of paranasal sinus disorders in horses.

2. Materials and Methods
Sinoscopy is performed with the horse sedated and restrained in a set of stocks or similar restraint as would be typically used for a dental procedure. Sedation can be accomplished through any number of approaches well-reviewed by Vigani et al.,3 but for
the general practice setting we have found IV administration of detomidine HCL (0.01–0.02 mg/kg) and morphine sulfate (0.2–0.4 mg/kg) to be simple and effective and is given once and then thereafter as needed to effect. We have found the trephination site in the frontal sinus to be the most useful given that it allows direct access and visualization of the frontal, dorsal conchal, and caudal maxillary sinuses; and indirect access to the ventral conchal and rostral maxillary via fenestration of the ventral conchal bulla, more accurately termed the bulla of the septum sinus maxillarium or maxillary septum bulla (MSB). The site for trephination of the frontal sinus has been described previously. Briefly, the trephine is centered 60% of the distance from midline to the medial canthus and 0.5 cm caudal to a line connecting both medial canthi. An area surrounding the trephination location is clipped and prepped in a routine manner. Although specific nerve blocks to provide local anesthesia to the part of the skull to be entered have been described, we have found local infiltration of 5–10 mL of mepivicaine subcutaneously at the planned site of trephination to be effective and simple (Fig. 1). A C-shaped incision is then made centered around the trephine hole with the base of the ‘C’ located axially (Fig. 2). A linear incision centered over the planned site of trephination is also acceptable. The incision is made to the underlying bone and the resulting flap, including the periosteum, is dissected off the bone with a periosteal elevator or scalpel (Fig. 3). The trephine hole is then made, while protecting the flap, with either a handheld gault trephine or a sterile hole-saw and a portable drill, both of which are available at local hardware stores (Fig. 4). The diameter of the tre-
A phine hole needs to be large enough to allow the endoscope (or arthroscope) and an instrument such as a Ferris-Smith rongeur or sponge forceps to pass simultaneously, typically 2–4 cm in diameter. Although a rigid arthroscope can be used, a flexible endoscope is more widely available and provides a superior examination of the paranasal sinus cavities because of the ability to navigate around structures within the sinus cavities (Fig. 5).\(^7\)

Following formation of the trephine hole, 60 mL of mepivicaine\(^e\) is applied topically throughout the exposed sinus cavity prior to examination to decrease sensation during intrasinus manipulations. The exact procedure from this point forward depends on the exact disease within that specific sinus cavity. Typical manipulations include a complete exploration of the exposed sinuses taking note of tooth roots in the caudal maxillary sinus, sinus lining throughout the sinuses, and accumulation of abnormal fluid or masses. The ethmoid turbinates are clearly visible just axial and caudal to the trephine location. The MSB is typically identified axial to the infraorbital canal, although portions can be located abaxially as well. In cases of suspected infection this bulla is easily removed with sponge forceps or rongeurs allowing removal of inspissated pus and lavage of the infected area (Fig. 6). The rostral maxillary sinus is located abaxially to the infraorbital canal and just rostral to the caudal maxillary sinus. Removal of the septum between these sinuses can improve visualization and drainage of the rostral maxillary sinus. Any abnormal tissues can be biopsied and samples taken for culture and sensitivity. Sinus cysts can be visualized and diagnosed by this approach, and in select cases occasionally removed. Similarly, small ethmoid hematomas located in the sinuses can be identified and diagnosed and the occasional hematoma may be amenable to either removal or intra-lesional injec-

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**Fig. 4.** Left to right, An example of a galt trephine, available from many instrument suppliers. An example of a hole-saw available, from hardware stores. Trephine hole partially complete. Complete trephine hole with view into the sinus cavity.

**Fig. 5.** Flexible endoscope and Ferris-Smith rongeur simultaneously inserted through trephine for biopsy and removal of unwanted tissue.

**Fig. 6.** View from frontal trephine location looking rostrally showing infraorbital canal, fenestrated MSB, ventral conchal sinus, small portion of rostral maxillary sinus, and caudal maxillary sinus. Rostral is to the bottom of the image, caudal to the top; left side of the image is medial and right side is lateral.
tion via this approach. Again the exact procedure performed will depend upon the disease present at the time of surgery. Closure is easily accomplished by suture of the periosteum and skin or simply skin staples. The author prefers skin staples because this allows easy re-entry should the need arise for continued therapy (i.e., sinus lavage due to infection) or for repeat sinoscopy if hemorrhage has prevented a complete examination at the time of the initial surgery.

It is worth mentioning that sinoscopy can be performed directly into both the rostral and caudal maxillary sinuses (Fig. 7). The trephination site for the caudal maxillary sinus is 2 cm rostral and 2 cm ventral to the medial canthus. The trephination site for the rostral maxillary sinus is 40% of the distance from the rostral end of the facial crest to the level of the medial canthus and 1 cm ventral to a line joining the infraorbital foramen to the medial canthus. These direct approaches may be indicated when visualization of only that part of the sinus is required. These approaches may be beneficial and provide direct access to specific structures (i.e., tooth roots) but limit ability to examine the entire paranasal sinus cavity, which is afforded by an approach to the frontal sinus.

We have performed this procedure on 25 horses in the past 3 years as the sole means of either diagnosis and treatment (six horses) or as the sole means of treatment (19 horses). In addition to these 25 horses we have performed standing sinoscopy in conjunction with a more traditional sinusotomy in six horses. This was performed to re-evaluate the initial lesion or treat recurrence of the initial lesion (i.e., return of previously treated ethmoid hematoma) in four horses or in two horses sinusoscopic evaluation of the sinus confirmed that the best definitive surgical approach was a traditional sinusotomy because of horse temperament (one horse) or size and location of a neoplasm (one horse). In all horses there were no surgical or postoperative complications related to the surgery although 11 horses required at least one more sinoscopy at a later date to treat recurrence of the original lesion. Of the 25 horses in which this was the sole surgical procedure performed, 16 were either primary or secondary bacterial sinusitis with inspissated pus in the ventral conchal sinus, five were paranasal sinus cysts, two were ethmoid hematomas located in the sinus cavity, and two were bone sequestra within the sinuses. The five paranasal sinus cyst cases treated in this manner were small cysts easily visualized and completely removed via sinoscopy. This approach was not considered for larger, incompletely visualized cysts. Similarly, the two cases of ethmoid hematomas treated in this manner were small extensions of nasally located hematomas that extended into the sinus cavity and were removed and the attachments injected with formalin. In all five cases of sinus cysts and both of these small ethmoid hematomas one surgical intervention was all that was required and at the time of follow-up there was no evidence of recurrence.

Sinoscopy using a flexible endoscope or rigid arthroscopy in the standing sedated horse is technically simple to perform and requires virtually no specialized equipment that the majority of equine practitioners do not already own. Due to the high prevalence of sinus disease in horses the ability to perform this technique will add a useful skill set to the general equine practitioner and increase their ability to diagnose and treat paranasal sinus disease in horses. Although this technique will not replace other, more advanced imaging modalities or more invasive surgical intervention, it does, however, provide the general practitioner with an additional tool to evaluate and treat horses with paranasal sinus disease. There are minimal complications of sinoscopy and the cost of this procedure will vary but because of lack of need for additional equipment the cost will not be high resulting in increased ability for practitioners to successfully diagnose and treat sinus disease in horses.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author declares no conflicts of interest.

References and Footnotes


Fig. 7. Diagram depicting trephination sites in the frontal, caudal maxillary, and rostral maxillary sinus.


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Warmblood Horses With Polysaccharide Storage Myopathy: Clinical Characteristics and Muscle Glycogen Concentrations

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Only a small percentage of Warmblood horses (WBs) have the gene mutation that causes type 1 polysaccharide storage myopathy (PSSM), and like other breeds commonly have a history of rhabdomyolysis. However, WBs with PSSM type 2 are more likely to present with gait abnormalities, and were unlikely to have elevated muscle glycogen concentrations. Authors’ addresses: Hagyard Equine Medical Institute, 4250 Iron Works Pike, Lexington, KY 40511 (Lewis); Michigan State University, Department of Large Animal Clinical Sciences, Lansing, MI 48824 (Valberg); Wilhite and Frees Equine Hospital, Peculiar, MO 64078 (Nicholson); e-mail: susannah.lewis@gmail.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Polysaccharide storage myopathy (PSSM) is a commonly diagnosed, poorly characterized myopathy in Warmblood horses (WBs) that is differentiated into type 1 (PSSM1; caused by GYS1 mutation) and type 2 (PSSM2; unknown etiology).

2. Materials and Methods
A database with 3602 clinical muscle biopsy submissions was utilized to retrospectively analyze signalment and clinical signs in WBs (n = 16) and non-WBs (n = 433) with PSSM1; WBs (n = 188) and non-WBs (n = 646) with PSSM2; and WBs without PSSM (n = 278). Muscle glycogen concentrations were measured for PSSM1 (n = 10), WB-PSSM2 (n = 10) and biopsies without pathological changes (n = 19).

3. Results
Exertional rhabdomyolysis was the most common clinical sign reported in any breed with PSSM1 (WBs: 12/16; 86%; non-WBs: 223/303; 74%) and in non-WBs with PSSM2 (221/436; 60%), but not WBs with PSSM2 (39/147; 27%). Gait abnormality was the most common clinical sign in WBs with PSSM2 (97/147; 66%). Based on detailed lameness examinations and bone scans from nine WBs with PSSM2, the gait abnormality was described as a mild, poorly localized, hindlimb lameness or stiffness. Gait abnormality was less common in WBs without PSSM (106/278; 33%), WBs with PSSM1 (1/16; 7%), and non-WBs with PSSM2 (176/436; 40%). Muscle glycogen concentrations in PSSM1 were significantly higher (1.4×) than WBs with PSSM2 and WBs and non-WBs without histopathologic abnormalities.

Research Abstract—for more information, contact the corresponding author
Acknowledgments
All research was conducted at the University of Minnesota.

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Dr. Valberg and colleagues license the PSSM1 genetic test mentioned in this paper and Dr. Valberg receives royalties from the test. Drs. Lewis and Nicholson have no conflicts to declare.

Fauna L. Smith, DVM*; K. Gary Magdesian, DVM, DACVIM, DACVECC, DACVCP; Adam O. Michel, DVM; Betsy Vaughan, DVM; and Christopher M. Reilly, DVM, MAS, DACVP

This is the first report of equine hemorrhagic cystitis, which has features both grossly and histologically that can be mistaken for neoplasia. Lesions resolved in all cases and all horses recovered. Authors’ addresses: Veterinary Medical Teaching Hospital (Smith, Michel), Department of Medicine (Magdesian), Department of Surgical & Radiological Sciences (Vaughan), Department of Pathology, Microbiology & Immunology (Reilly), University of California–Davis, Davis, CA 95616; e-mail: flsmith@ucdavis.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Objective
To characterize a clinical syndrome of hemorrhagic cystitis in horses.

2. Materials and Methods
This was a retrospective case series in which a search of the medical record database (2004–2015) was performed for horses with selection criteria for “hemorrhagic cystitis: hematuria and cystoscopic evidence of cystitis.”

3. Results
Hemorrhagic cystitis was identified in nine horses, all males. Male horses were overrepresented in the cystitis group compared with the hospital population ($P = .03$; odds ratio, 13.5 [0.78–23.16]). All horses had a history of gross hematuria, confirmed by urinalysis. Cystoscopy revealed apically oriented, raised, hemorrhagic lesions of the bladder mucosa. Bladder wall hemorrhage with neutrophilic infiltration (n = 4) was the most common histopathologic finding, but one horse each had findings consistent with transitional cell dysplasia or suspected transitional cell carcinoma. All horses were treated with trimethoprim sulfa and seven returned for follow-up cystoscopy. Median time to cystoscopic resolution was 43 days. Lesions and hematuria resolved in all cases, and horses returned to their previous function.

4. Discussion
Equine hemorrhagic cystitis has not been previously described. All affected horses were male. Although some histologic lesions had dysplastic or neoplastic features, all affected horses responded rapidly to therapy with resolution of lesions. These findings make this an important differential diagnosis to consider when bladder neoplasia is suspected grossly or histologically in horses with hematuria.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors declare no conflicts of interest.

Research Abstract—for more information, contact the corresponding author
Equine Tongue Tumors: A Multi-Center Retrospective Study

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Tongue tumors are rare in horses and can be found following presentation for various complaints. Outcome depends on tumor type, with squamous cell carcinoma being the most common tumor with the least favorable prognosis. Biopsy should be considered the central diagnostic procedure.

1. Introduction
Tumors of the equine oral cavity are rare and, due to a lack of visibility, may not be diagnosed for a prolonged time. While various types of tumors have been found in the equine tongue, information about clinical signs, treatment options, and outcome is very limited.

2. Materials and Methods
Medical records (1997–2014) from eight practices were reviewed. Horses met inclusion criteria if ante-mortem diagnosis of a lingual tumor was made and confirmed by cyto- or histopathology.

3. Results
Twelve horses with tongue tumors, including squamous cell carcinomas (n = 4), melanomas (n = 2), anaplastic carcinomas (n = 2), mast cell tumors (n = 2) a B-cell lymphosarcoma, and a neuroendocrine tumor were identified. Presenting complaints included a tongue mass (n = 4), dysphagia (n = 3), a...
tongue wound (n = 2), intermandibular swelling (n = 1), and stridor (n = 1). Seven horses underwent surgical treatment, with six showing no signs of recurrence in the following year. One mast-cell tumor responded to conservative treatment, whereas all horses with squamous cell carcinoma were euthanized following palliative treatment.

4. Discussion
Suspicion of a tongue laceration or lingual mass is a common presenting complaint for horses with tongue tumors and biopsy is required for final diagnosis. While prognosis for lingual squamous cell carcinomas was grave, surgical treatment for other tumor types carried a good long-term prognosis.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
Case-Control Study of Pasture- and Endocrinopathy-Associated Laminitis in Horses

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Horses with an increased body condition, generalized and/or regional adiposity, a historic diagnosis of an endocrinopathy, and recent glucocorticoid administration are at an increased odds for the development of pasture-and endocrinopathy-associated laminitis (PEAL). Authors’ addresses: Department of Large Animal Clinical Sciences, Texas A&M University, College Station, TX 77843 (Coleman, Cummings, Cohen); The Ohio State University, Columbus, OH 43210 (Belknap, Moore); Department of Veterinary Clinical Sciences, Louisiana State University, Baton Rouge, LA 20803 (Eades); Hagyard Equine Medical Institute, 4250 Iron Works Pike, Lexington, KY 40511 (Fraley, Hunt); Department of Clinical Studies, New Bolton Center, University of Pennsylvania School of Veterinary Medicine, Kennett Square, PA 19348 (Galantino-Homer); College of Sciences, Massey University, 4442, New Zealand (Geor); University of Minnesota, Department of Veterinary Population Medicine, St. Paul, MN 55108 (McCue); Orthopaedic Research Center, Colorado State University, Fort Collins, CO 80526 (McIlwraith); Department of Large Animal Medicine, The University of Georgia College of Veterinary Medicine, Athens, GA 30602 (Peroni); Department of Large Animal Clinical Sciences, University of Saskatchewan, Saskatoon, SK S7N 5B4, Canada (Townsend); Virginia Tech Equine Medical Center, Leesburg, VA 20176 (White); Department of Population Medicine and Diagnostic Sciences, Cornell University College of Veterinary Medicine, S1–072 Schuman Hall, Ithaca, NY 12853 (Ivanek-Miojevic); e-mail: mcoleman@cvm.tamu.edu. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
Laminitis is a debilitating disease of the foot resulting in severe pain, lameness, and loss of athletic performance. Improving our knowledge and understanding of risk factors for development of pasture- and endocrinopathy-associated lameness (PEAL) through epidemiologic studies could guide future investigation into prevention and control of this form of disease in

Research Abstract—for more information, contact the corresponding author

NOTES
horses. The objective of this study was to determine risk factors for the development of PEAL in North America.

2. Materials and Methods
This case-control study was performed in North America from 2012 to 2015. Participating veterinarians provided data from an index case of PEAL and two control populations, a healthy horse and a lame horse. Data from affected and unaffected horses were compared by use of conditional logistic regression analysis.

3. Results
A total of 199 horses with acute, incident PEAL, 198 healthy controls, and 153 lameness controls were included. Horses with an obese body condition score (BCS ≥ 7), generalized and/or regional adiposity, a historic diagnosis of an endocrinopathy, and recent glucocorticoid administration were at an increased odds of developing PEAL.

4. Discussion
This study provided important information about the risk of PEAL in horses in North America. Early identification of horses at risk of obesity and/or endocrinologic disease may be important factors in reducing the burden of PEAL.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

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Foal-Level Risk Factors Associated With the Development of *Rhodococcus equi* Pneumonia on a Single, Large Quarter Horse Farm

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The cumulative incidence of disease on the farm varied significantly by year. Foals with a prior disease diagnosis other than *Rhodococcus equi* (*R. equi*) were less likely to develop *R. equi* pneumonia.

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1. Introduction

While all foals are exposed to the *Rhodococcus equi* (*R. equi*) and seroprevalence among foals is high, only some foals residing on endemic farms develop clinical signs of disease. Thus, the purpose of this study was to identify foal-level risk factors associated with the development of *R. equi* pneumonia among foals on a single, large breeding farm with a recurrent problem of *R. equi* pneumonia.

2. Materials and Methods

A retrospective cohort study was conducted using data from foals born at a single farm in Texas between 2009 and 2011. Dam-level, foal-level, and health-related data was collected from all foals. Independent variables were analyzed with logistic regression, controlling for the effect of year.

3. Results

Data from 787 foals born on the farm from 2009–2011 were collected, of which 209 (27%) developed *R. equi* pneumonia. The cumulative incidence of disease on the farm varied significantly by year. Foals that were diagnosed with a prior morbidity besides *R. equi* were less likely to develop disease.

4. Discussion

No significant foal-level factors were identified in association with the development of *R. equi* pneumonia. The finding that foals with other respira-
tory tract infections are less susceptible to *R. equi* pneumonia is biologically interesting and might lead to strategies for immunoprophylaxis. Heritability of the disease in this population should be further investigated.

**Acknowledgments**

*Declaration of Ethics*

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**

The Authors declare no conflicts of interest.

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How to Feed Horses With Exertional Myopathies

Stephanie J. Valberg, DVM, PhD, DACVIM, DACVSMR

1. Introduction
Dietary manipulation is a particularly attractive and effective means to manage many muscle disorders in equine athletes. Exertional myopathies such as polysaccharide storage myopathy (PSSM) and recurrent exertional rhabdomyolysis (RER) improve with specific diet and exercise regimes. Owners usually want a simple one size-fits-all strategy; the “one pound of fat a day regime.” However, this approach does not work for the range of equine athletes veterinarians encounter in practice. The recommended amount of nonstructural carbohydrate (NSC) and fat for horses with exertional myopathies is provided as a proportion of daily caloric intake (digestible energy). This brief how-to paper is designed to assist practitioners in converting percent digestible energy to the amount of NSC and fat to feed horses with myopathies. A comprehensive review of feeding and exercise regimes for exertional myopathies in horses can be found at Valberg et al, 2012.5 In the examples provided in this how-to paper ballpark figures for nutrient content of hay and concentrates are used and two 500-kg horses, one with PSSM and one with RER, are used. In reality, a horse’s weight will vary and should be accurately estimated, hay should be analyzed for nutrients, feed manufacturers contacted to obtain the exact content of their feeds, and a professional nutritionist consulted to properly balance the ration. In addition, dietary changes must go hand in hand with an exercise program because changing diet without regular exercise will not produce the desired level of improvement in the exercise tolerance of horses with exertional myopathies.

2. Determining Calorie Intake and NSC Content
The principle dietary recommendation for exertional myopathies in horses is to decrease NSC content and increase fat content. For horses with PSSM the NSC target is to provide 10–15% of the total calories in the diet as NSC and the target for RER <20% of the total calories in the diet provided as NSC.1,2 The target for fat content for PSSM horses is 10–15% of daily calories supplied as fat and for horses with RER 10–20% of daily calories or greater supplied as fat if needed to maintain weight.1,2

Caloric Intake
Calculations of caloric needs factor in body condition scores, intended level of use, and hard/easy keeper status and are measured in megacalories (MCal). The commonly used term “calories” for humans is actually a kilocalorie. A 500-kg easy-keeping horse on light exercise (45 min/d of walk trot canter, 4 d/wk) may need 18 MCal/day and an athletic hard keeper in full work 35 MCal/day (>1 h/d of walk, trot, canter, gallop ± jumping, 5–6 d/wk).

NSC Content
Water-soluble sugar (largely from hay) and starch (largely from concentrate) are both components of NSC content.
Easy Keeper With PSSM
Target NSC content ≤15% of daily caloric intake.

- 15% × 18 MCal/day = 2.7 MCal/day
- A conversion factor for MCal to grams (g) NSC is used: 2.7 MCal × 1 g NSC/0.004 MCal = 675 g NSC/day

Hard Keeper With RER
Target NSC content ≤20% of daily caloric intake.

- 20% of 35 MCal = 7 MCal
- 7 MCal × 1 g/0.004 MCal of NSC = 1750 g of NSC/day

Note the wide margin of difference in the amount of NSC tolerated by horses with PSSM and RER depending on their underlying caloric intake.

3. Selecting a Forage
Calories
An average hay provides 2 MCal/kg and in these examples will be fed at 1.5% of 500 kg body weight.

- 1.5% of 500 kg = 7.5 kg of hay
- Calories provided by hay: 7.5 kg hay × 2 MCal/kg = 15 MCal/day

Easy Keeper With PSSM
The easy-keeping 18 MCal/day horse would have 3 additional MCal that could be provided in a concentrate or oil.

Hard Keeper With RER
The hard-keeping Thoroughbred with RER requires 15 additional MCal/day.

4. NSC Content of Forage
Hay is by weight the largest component of a horse’s diet, a major source of sugar, and therefore the NSC content of hay affects the total NSC in the diet. The only way to know the NSC content of hay is to perform a nutritional analysis. Research has defined an upper limit for NSC in hay for PSSM horses of 12% NSC by weight of the hay to avoid an insulin response. Consuming hay with 11% or lower NSC does not produce a significant insulin response. Insulin stimulates glycogen synthase 1, the overactive enzyme responsible for type 1 PSSM. Hay usually has less than 3% fat by weight.

NSC provided by 7.5 kg of 11% NSC hay

7.5 kg hay × 11% NSC = 825 g

The easy keeper with PSSM has exceeded the target NSC (675 g) with this amount of hay. A lower-NSC hay or a lesser amount of hay may be required.

The hard keeper with RER is under the target NSC (1750 g NSC target) and has 925 additional g of NSC that can be provided by a concentrate or more hay or hay with a higher NSC.

5. Adding Fat
Serum creatine kinase (CK) activity in horses with PSSM or RER declines significantly when horses are fed a variety of natural oils or feeds containing rice bran. One type of fat has not been shown to be beneficial over another in short-term feeding trials of horses with PSSM or RER with the exception of short-chain, odd-carbon, synthetic fats, which cause excessive increases in insulin and serum CK. Such odd-carbon fats are not commercially available in any feeds or supplements.

Easy Keeper With PSSM
Fat is calorie dense (1 g provides 0.009 MCal) and can readily cause weight gain in easy-keeping PSSM horses. For an overweight PSSM horse, fasting for 6 hours before exercise rather than feeding fat is a means to naturally increase needed serum-free fatty acids and avoid weight gain. Once a healthy weight is achieved, fat can be added to the diet. As horses increase their exercise intensity owners often must increase the amount of fat being fed or signs of exercise intolerance return.

At a normal body weight the target fat intake is 10% of daily calories for PSSM.

- 10% of 18 MCal/day of caloric intake = 1.8 MCal of fat
- 1.8 MCal × 1 g fat/0.009 = 200 g of fat

Oils
- One cup of vegetable oil (223 g) would provide 2 MCal with no additional NSC
- This would provide 2 MCal/18 MCal × 100 = 11% of daily calories as fat, meeting the target.

Rice Bran
- 0.75 kg (1.7 lbs) of a commercial rice bran (~4 MCal/kg, 20% fat, 20% NSC)
- 0.75 kg × 4 MCal/kg = 3 MCal provided
- 0.75 kg × 20% = 150 g of fat; 150 g × 0.009 MCal/g = 1.45 MCal
- 1.45 MCal/18 MCal × 100 = 8% fat—less than the target
- 0.75 kg × 20% NSC = 150 g NSC, which when added to the 825 g provided by the hay further exceeds the target of 675 g NSC

Thus, for an easy-keeping, fairly sedentary horses with PSSM, a straight fat supplement such as oil or a solidified fat may be a better choice than a high-fat concentrate feed that contains additional NSC. This diet, however, would need a ration balancer to provide additional vitamins, minerals, and amino acids. The most common mistake owners make in feeding horses with PSSM is to select a concentrate with 10–20% fat by weight and feed a small amount to avoid weight gain. As can be seen in the above example, feeding 1 lb (0.45 kg) of rice bran would
only provide 90 g of fat, which would provide less than 5% of daily calories as fat.

**Hard Keeper With RER**

At 35 MCal/day this horse could readily consume more rice bran or a commercial 3.3 MCal/kg high-fat feed (12.5% fat by weight) with a low NSC content (10% by weight). Oils alone are not usually a good choice for hard keepers given that it is often difficult to get a hard-keeping horse to consume the amount of oil needed to achieve a target of 15–20% daily calories as fat.

Using the commercial low-starch high-fat feeda

- 6 kg feed × 3.3 MCal/kg = 19.8 MCal/day from concentrate + 15 MCal/day from hay = 35 MCal/day, which meets the daily target.
- 6 kg feed × 10% NSC = 600 g NSC
- The total NSC in the ration = (600 + 825 g from hay) × 0.004 MCal/gram = 5.7 MCal/day
  - Percentage of calories from NSC = 5.7 MCal/35 MCal × 100 = 16%, which meets the target of <20%
- 6 kg feed × 12.5% fat = 600 g of fat × 0.009 MCal/g = 6.8 MCal/day
  - Percentage calories from fat = 6.8 MCal/35 MCal × 100 = within the target of 15–20%

These examples illustrate why it is not possible to recommend one amount of a high-fat low-starch feed for exertional myopathies and why feeding programs must be designed for each individual horse based on the percentage of daily calories.

There are numerous other very important factors that go into balancing a ration that are not discussed in this simplified context. Feeds are designed to be balanced when fed at the manufacturer’s recommended amounts. When owners feed less than the recommended amount, the ration will not be balanced for protein, vitamins, and minerals. A consultation with a nutritionist can address these imbalances and aid in selecting from the many high-fat, low-starch and fat supplements currently available from every major feed company.

**6. Expectations**

The beneficial effect of low-starch high-fat diets require that horses be trained daily, which will enhance enzymes involved in fat and glucose metabolism. It is important to note that many horses with chronic forms of exertional rhabdomyolysis will always have an underlying predilection for muscle soreness and the best that can be performed is to manage horses to minimize clinical signs. With adherence to both the diet and exercise recommendations, 70–75% of Quarter Horses and Warmbloods with PSSM show notable improvement in clinical signs and many return to acceptable levels of performance.7,8 There is, however, a wide range in the severity of clinical signs shown by horses with exertional myopathies; those horses with severe or recurrent clinical signs will require more stringent adherence to diet and exercise recommendations to regain muscle function. PSSM horses that also have the mutation for malignant hyperthermia do not respond as well to diet and exercise recommendations and may continue to develop exertional rhabdomyolysis with the possibility of a fatal episode.9

**Acknowledgments**

**Declaration of Ethics**

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**

Dr. Valberg and colleagues license the PSSM1 genetic test and receive royalties. Dr. Valberg helped to develop the feed, Re-Leve, and receives royalties from the sale of the product.

**References and Footnote**


a Re-Leve, Kentucky Equine Research, Versailles, KY 40383.
How to Feed Obese Horses and Ponies

Ingrid Vervuert, DMV

1. Introduction

Obesity is a common problem in horses and ponies, especially in the so-called easy keepers. Local or general adiposity and insulin resistance, as well as a predisposition to laminitis, were recently described as equine metabolic syndrome. Insulin resistance is either defined as resting insulin > 20 μU/mL or by abnormal glycemic and insulinemic responses to glucose and/or insulin challenges.

In the insulin-resistant state, tissues such as skeletal muscle or adipose tissue do not properly respond to insulin, thereby causing a reactive response in insulin secretion by pancreatic β-cells. General or regional obesity has been associated with a chronic state of inflammation and insulin resistance in humans and animal species such as the horse. Beyond that, equine studies highlight obesity and insulin resistance as a main contributing factor for developing laminitis and impaired reproduction. Pony breeds seemed to be more predisposed to becoming insulin resistant and to developing laminitis than horse breeds. Because increased systemic inflammation is known to increase the risk for laminitis, obesity-associated insulin resistance and inflammation have been highlighted in the horse.

2. Effects of Diet on Obesity and Insulin Resistance

In humans and animal species such as the horse, it is hypothesized that periodic postprandial hyperinsulinemia may promote the development of insulin resistance. The long-term feeding (from birth to weaning, 200 d) of a starch- and sugar-rich concentrate in Thoroughbred foals resulted in a decreased insulin sensitivity after weaning when compared with animals fed with a fat- and fiber-enriched concentrate. In Thoroughbred geldings, feeding a concentrate rich in sugar and starch inconsistently affected insulin dynamics when compared to a concentrate rich in fat and fiber; however, results were partly confounded by the effects of body condition. In Standardbred horses, diets rich in starch and sugar have been associated with decreased insulin sensitivity and impaired glucose tolerance within 6 weeks. It is interesting to note that subsequent physical conditioning reversed the effect of diet on insulin sensitivity.

Based on these studies, dietary strategies should be developed to lower insulin concentrations and improve insulin sensitivity in the horse. These strategies include diets with low glycemic responses, progressive weight loss, and regular exercise.
3. Energy Restriction
Several studies have shown that progressive weight loss had significantly improved insulin effectiveness in insulin-resistant ponies, highlighting the link between obesity and insulin resistance.\(^{14,15,17}\)

4. L-Carnitine
Nutraceuticals such as L-carnitine or trace elements, which may facilitate body weight (BW) loss or improve insulin sensitivity in humans, are of interest. However, Schmengler et al.\(^{18}\) showed no significant advantage of L-carnitine supplementation over placebo with respect to the metabolic profile during body weight reduction, suggesting that endogenous L-carnitine synthesis is sufficient to facilitate lipid and glucose metabolism in ponies.

5. Zinc
Several studies in humans, rats, and mice have investigated the role of zinc (Zn) status in the management of insulin resistance. Zn seemed to stimulate insulin action by increased activities of insulin-independent glucose transporters and by an improved binding ability of insulin to its receptors.\(^{19}\) Zn supplementation above recommendations might have some potential to improve glucose tolerance in horses; however, further studies in horses are needed.

6. Chromium
Chromium (Cr) is an essential trace element that is involved in the metabolism of carbohydrates, lipids, and proteins by amplifying the activity of insulin. In diabetic humans and rats, Cr supplementation has been shown to increase the cellular uptake of glucose and stimulate insulin metabolism. In horses with hyperinsulinemia, Cr supplementation failed to alter glucose tolerance;\(^{20}\) however, the daily Cr dosage (~ 10 μg/kg BW) was far below the recommended doses in humans (20 μg/kg BW). Cr supplementation for 4 weeks improved glucose metabolism in obese ponies and horses, suggesting that Cr facilitated insulin signaling.\(^{11}\) However, it must be emphasized that the ponies and horses still had impaired glucose regulation as indicated by supraphysiological glucose and insulin responses to the starch tolerance test when compared with healthy horses.

7. Iron
In recent years, a number of reports in humans have demonstrated a relationship between serum and total body iron (Fe) reserves and the risk for type 2 diabetes.\(^{21}\) It has been hypothesized that the formation of reactive oxygen species and oxidative tissue damage catalyzed by Fe contributes initially to insulin resistance.\(^{21}\) Mechanisms underlying the relationship between Fe and diabetes are not fully understood and prospective studies in horses are missing. Currently, it might be advisable to avoid Fe supplementation in horses with equine metabolic syndrome (EMS).

8. Cinnamon
In humans, contradicting results exist regarding the efficacy of supplementing cinnamon to the diet to improve glycemic control. Lower doses of 1.5 g cinnamon per day (~ 18 mg/kg BW) did not improve glycemic control in type 2 diabetes,\(^{22}\) whereas higher doses (> 36 mg/kg BW) seemed to ameliorate glucose metabolism in patients with type 2 diabetes.\(^{23}\) In vitro studies suggest that cinnamon might increase the amount of proteins involved in insulin signaling and glucose transport. In horses, some compounded feed contains cinnamon; however, scientific data about dosing and potential effects are lacking.

9. Conclusion
Obesity is a common problem in horses and ponies, especially in the so-called easy keepers. Obese animals are more predisposed to becoming insulin resistant and to developing laminitis than lean animals. Body weight reduction is one of the key issues to improve metabolic abnormalities. However, the effect of energy restriction to reduce body weight is not further enhanced by supplements such as L-carnitine or chromium.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

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The Author declares no conflicts of interest.

References


How to Feed Horses With Gastric Ulcer Syndrome

Ingrid Vervuert, DMV

1. General Considerations
Equine gastric ulcer syndrome (EGUS) is a very common health problem in adult horses and foals. The prevalence of EGUS in Thoroughbred racehorses is estimated to be >80%. The prevalence of EGUS in foals ranges between 30 and 50%, particularly in weanlings. In a recent consensus statement it was suggested that equine squamous gastric disease and equine glandular gastric disease are more specific than the term EGUS given that these terms describe the affected gastric regions.

In addition to the continuous production of hydrochloric acid by the parietal cells of the glandular mucosa in horses, several other mechanisms are thought to induce gastric ulceration. Other acids, including bile acids or short-chain fatty acids (SCFAs), have been implicated in acid injury. For example, SCFAs such as butyrate, acetate, and propionic acid act synergistically with hydrochloric acid and induce similar effects by penetrating the mucosa, resulting in cellular inflammation as well as interacting with the sodium transport system. Furthermore, carbohydrate fermentation by gut microflora produces lactic acid and induces increased tissue permeability and secondary damage to the equine stomach mucosa. In contrast with the severe effect on human patients, Helicobacter pylori is only sporadically identified in the stomach of horses with EGUS, thus, the role of this pathogen remains unclear.

Risk factors, such as nonsteroidal anti-inflammatory drugs, high-grain diets, starvation periods for 24 hours, stall confinement with no access to pasture, and strenuous exercise or transport stress have been identified to induce equine gastric ulcer syndrome. In foals, the weaning process is well known to induce gastric ulceration.

Several studies have confirmed an improvement of healing gastric ulcers by administering drugs, such as omeprazole, cimetidine, and ranitidine.

2. Feeding Management
In addition to medical treatment, optimizing feeding and housing management is highly recommended. In exercising horses, grain intake should be limited to a maximum of 1 g starch per kg body weight per meal. Special attention should be spent on the forage intake. Forage should be provided ad libitum or at least fed to a daily minimum of 1.5-2% of body weight. The practice of feeding hay first followed by grain leads to an optimal mixture of gastric content. In several studies, feeding alfalfa hay is reported to have a protective effect on gastric mu-
cosa by buffering gastric pH due to its high contents of calcium, magnesium, and protein. For example, feeding alfalfa hay combined with grain to six adult horses over a period of 14 days increased pH in gastric juice over 2–5 hours after feeding.

Furthermore, the number and severity of gastric mucosal lesions located in the Pars nonglandularis were significantly lower compared with horses fed bromegrass hay. Lybbert published similar results in 24 yearlings. In a crossover study, yearlings were either fed either coastal Bermuda grass hay or alfalfa hay over a period of 28 days with a 21-day washout period. All horses underwent a moderate training program during the study. Only one of the 24 horses fed alfalfa hay showed an increase in severity score in contrast with 10 of 24 horses in the Bermuda grass group. However, recent studies feeding alfalfa chaff failed to improve gastric mucosal lesion scores in weanlings and adult horses. In fact, significantly higher lesion scores in the pyloric region were detected when feeding alfalfa chaff.

In this study 38, weanlings aged between 172–174 days were randomly allocated to two forage feeding groups: alfalfa chaff and hay. Gastroscopic examination was performed immediately before weaning and after a feeding period of 15–16 days. Weaning induced gastric lesions at the major and minor curvatures of both Pars nonglandularis and Pars glandularis in both forage groups. However, a significantly higher number of lesions at the pylorus were seen in the alfalfa chaff group only. These results were confirmed in repletion trials in weanling as well as in adult horses. A possible explanation for the changes at the pylorus might be the harsh acanthous structure of alfalfa chaff that might cause mechanical injury at the pylorus. The pyloric region is an area of the stomach with high motility. It is speculated that the movement of the alfalfa stems might excoriate the mucosa during passage. This initial injury of the glandular mucosa might leave the pylorus more vulnerable to the insults of SCFAs, hydrochloric acid, and/or bile salts.

3. Conclusion

In conclusion, providing grass hay ad libitum or at least to a daily minimum of 1.5–2% of body weight, and a significant reduction in starch intake can be recommended to prevent gastric ulceration. Free access to pasture has been linked to the lowest incidence of gastric mucosa lesions.

Acknowledgments

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References

How to Feed Rapidly Growing Weanlings: Myth Versus Fact

Sarah Ralston, VMD, PhD, DACVN

1. Introduction
Rapid growth requires the presence of adequate amounts of protein with balanced essential amino acids and usable energy sources for soft tissue and skeletal growth: macro- and micro-minerals as the building blocks for bone, tendons and ligaments and, to a lesser degree, vitamins as the cofactors in the growth process. Inadequate or imbalanced provision of any of these will alter the developmental processes, possibly to the detriment of the young horse. The more rapid the rate of growth, the more critical the balances become and more quickly nutritional errors will manifest. Although horses will continue to grow and acquire skeletal strength and size for up to 6 years of age, after 12–18 months of age the rate of growth is slow enough that there is more tolerance of deficits/excesses in the rations.1

Traditionally it has been recommended that weanlings receive 50–60% of their caloric needs in the form of a grain-based concentrate1–3 and that high protein (>14% in total rations)2 fed to rapidly growing horses will cause developmental orthopedic disease. These are myths. The facts are that since 2004 it has been reported that even rapidly growing weanlings do as well, if not better when fed predominantly forage-based rations with little to no grain-based concentrates.4–9 In a series of experiments (2004–2006) we tested the hypothesis that rapidly growing draft cross weanlings (age 5–12 mo) could be fed forage-based rations with little to no grain included, as long as the nutrient profile of the feed met or exceeded the National Research Council (NRC)2,3 recommendations. The objectives were to compare growth and development of draft cross weanlings fed either forage-based total mixed-ration (TMR) cubes vs traditional 50:50 forage:grain concentrate ration.

2. Materials and Methods
Each autumn, 12 weanling draft/Quarter Horse cross weanlings were purchased from a ranch in North Dakota. After training and adaptation to the conditions at our research facility, the horses were paired according to body weight and assigned to one of two treatments. Treatment 1 was a traditional ration consisting of 50% of the calories provided from either a pelleted feed formulated specifically for growth (Y)a or a pelleted feed formulated to meet or exceed requirements for all life stages (SF)b and free access to grass/legume mix hay. Treatment 2 consisted of horses that had free access to a forage-based total mixed-ration (TMR) cube formulated, based on forage analysis, to meet or exceed NRC recommendations for energy, protein,
calcium, and phosphorus intakes. In 2004 and 2005, the TMR contained 10% added grain, in 2006 the TMR had 10% wheat bran added. The rations were fed to the horses in feeders in their individual stalls, with the concentrate divided into two feedings, morning and late afternoon and the hay and TMR replenished only once a day in the morning. The weight of the hay and TMR offered were recorded daily and leftovers were removed each morning and weighed. All horses had access to white salt blocks and water at all times. They were turned out in a dry lot daily for exercise for 5 to 6 hours with access to only salt and water. The weanlings were weighed and measured weekly for the next 4 months.

3. Results

The nutrient profiles of the rations given all 3 years are provided in Table 1. Weanlings fed the traditional rations (Treatment 1) had average daily gains (ADG) that met or slightly exceeded the 0.8 kg/day predicted by the NRC. Weanlings fed TMR (Treatment 2) had ADG that exceeded \(P < 0.05\) the gains of the traditionally fed horses (Fig. 1) even though their actual intakes of feed were slightly lower. There were two incidences of developmental orthopedic disease (DOD) in both 2005 and 2006 that were present before the study was initiated. In 2005, two weanlings had epiphysitis that resolved spontaneously during the trial period, one in each treatment group. In 2006, one colt had bilateral stifle OCD lesions (treated surgically), one filly had mild flexural deformities that did not change during the experimental period.

4. Discussion

There is increasing evidence that the previous recommendations\(^2\)\(^-\)\(^3\) that weanling horses must be fed rations composed of 60%-40% grain-based concentrates: forage are wrong. Good-quality pastures (16–20% protein dry matter, calcium \(>0.6\%), phosphorus between 0.45% and 0.6%, low to no oxalates) with adequate rainfall can support normal-to-high growth rates in weanling Thoroughbreds with minimal to no concentrate supplementation.\(^4\)\(^,\)\(^9\) Even though the most recent NRC\(^3\) and research performed by feed companies\(^10\)\(^,\)\(^11\) suggest supplementing young horses with grain-based concentrates at the rate of 1–1.5% body weight (\(\sim 50\%\) of the total intake per day), Ralston et al\(^7\)\(^,\)\(^8\) and Kline\(^5\) documented excellent growth

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### Table 1. Average Recorded Nutrient Intakes of Draft Cross Weanlings Fed Either 50% of Their Recommended Caloric Intakes in the Form of Grain-Based Concentrates (Y* or SF*) With Free Access to Grass/Legume Mix Hay Versus Free Access to Forage-Based Total Mixed-Ration Cubes (TMR*) Fortified With Minerals as Needed Based on Forage Analysis and <10% Grain or Wheat-Bran Additives

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<td>Meal DE/kg DM</td>
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<td>2.2</td>
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<td>Phosphorus, %</td>
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<td>0.42</td>
<td>0.37</td>
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Abbreviations: DE, digestible energy; DM, dry matter of feed.
rates and body condition in weaning horses fed forage-based TMRs, balanced for minerals and protein (16–19%) but containing <10% grain-based products (~2.2 Mcal/kg) when compared with weanlings fed a traditional hay/grain-based ration wherein 50% of the total ration was a grain-based concentrate. The TMR rations were mixtures of specially collected grasses and alfalfa supplemented with mineral as needed, based on analyses of the forages used, to meet or exceed nutrient requirements for rapidly growing horses. In the studies by Ralston et al6–9 the young draft cross horses fed the TMR rations consumed between 2.7–3.1% of their body weights per day when fed free choice. Kline5 restricted the TMR (60% alfalfa hay, 15% tall fescue, and 25% oats) intakes to 2.5% body weight and still got higher growth rates than predicted (1.69 kg/d) and no gastric ulcerations in Standardbred weanlings compared with those fed a typical 50% forage: 50% grain ration (0.95 kg/d, gastric ulceration scores between 0.5 and 3 in all periods of the experiment).

It has been suggested that provision of moderate amounts of starch (20–30% non-structural carbohydrates [NSC] in a concentrate) might actually improve insulin sensitivity in young and adult horses and ponies despite stimulation of higher but physiologic secretion of insulin to a standardized challenge; however, it is obvious that high starch/sugar rations (>30% NSC) are not necessary for good-quality growth and development in young horses. High-protein rations (>14–16% in total rations) were incriminated in the mid 1970s as a significant cause of development of orthopedic diseases in rapidly growing foals, resulting in a widespread belief that protein should be restricted to 14% or less in rapidly growing foals. However, numerous studies since that time have repeatedly demonstrated that as long as the mineral intake is adjusted to meet the needs of the rapidly growing young horses, protein intakes as high as 20% caused no significant problems. It also seems that the amino acid balance of the protein fed to a weanling or yearling is important, with lysine and threonine identified as the two most limiting amino acids. Staniar1 obtained acceptable growth rates in weanling Thoroughbreds fed a ration of unspecified hay and 9% protein concentrate when the concentrate was supplemented with 0.6% lysine and 0.4% threonine. However, the ideal recommendation is that rapidly growing foals be fed rations that contain between 13 and 17% protein of good quality, preferably from legume (alfalfa or soybean meal) or milk-based sources.1,3

5. Summary

It is now apparent that high grain/starch rations are not necessary for optimal growth in weanlings as long as high-quality forages or forage-based feeds are available. As long as the energy, protein, and mineral needs of young, rapidly growing horses are met, optimum growth and development can be achieved without high starch and sugar content, which has been correlated with a higher incidence of gastric ulceration. High-protein rations per se do not cause DOD. Protein quality (lysine and threonine content) is as, if not more, important than quantity. Legumes such as alfalfa and clover are excellent sources of high-quality protein and should be included in the rations of rapidly growing young horses.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Author acknowledges the donation of feeds used in the research from both Nutrena, (Cargill Animal Nutrition) and Square Meals Feeds, LLC. The Author has served as a consultant for both companies.

References and Footnotes


"Nutrena Youth, Nutrena, Cargill Animal Nutrition, Minneapolis, MN 55440.

"Safe Choice, Nutrena, Cargill Animal Nutrition, Minneapolis, MN 55440.

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How to Feed a Senior Horse

Megan L. Shepherd, DVM, PhD, DACVN

1. Introduction

What is a senior or aged horse? The age at which horses are considered seniors or aged varies from 15 to greater than 20 years of age.1–3 Typically, the author does not consider a horse to be a senior until they are in their 30s from observations of horses remaining active and maintaining good condition through their 20s. There is individual variation with respect to the age at which special management is indicated. Owners in the United States and Australia report that less than 50% of their senior horses are retired.2,3 Of the nonretired senior horses in Australia, more than half worked a median of 1 hour per day 3 days per week and most were reported to work at moderate intensity.3 In the United States, 10% of unretired senior horses still compete.2

Age is a number, not a disease. However, there are conditions associated with advancing age in horses such as colic, pituitary pars intermedia dysfunction (PPID), dental disease, orthopedic disease, and under/overweight.2,4–6 PPID has been linked to alterations in insulin sensitivity or insulin resistance in horses and the subsequent hyperinsulinemia increases the PPID horse’s risk for laminitis.2,7 However, Mastro and colleagues8 reported that PPID in the senior horse (age 23–28 y) was not associated with altered insulin sensitivity. Mild dental abnormalities (points, hooks) do not warrant diet change9 and feeding long-stem forage may be beneficial in promoting even dental wear. However, feed and feed form should be reevaluated if a horse’s dental disease is progressed such that the horse quids to minimize feed losses and prevent weight loss. Dietary considerations age-related conditions may be helpful in improving the quality of life in the senior horse.

Key Nutritional Factors for the Senior

Water is the most important ingredient in any horse’s ration and special attention should be given to the senior with altered mobility or specific preference for water temperature.

Dietary Dry Matter, Energy, and Macronutrients

How much should you feed? This is a difficult question because it depends on the energy density of the feeds available and what the horse is willing to eat. Activity influences energy requirements and activity is thought to decline with advancing age. The digestible energy (DE) requirements for seniors are not known to be different than for adult horses. For the less or moderately active senior, DE requirements may be 30.3 kcal (reduced) to 33.3 kcal (average adult) per kg of horse.10

Expected dry matter (DM) intake for the adult horse is 2% body weight in DM per day or 20 lb DM per 1000-lb horse. Commercial senior feeds and
needs to be for the horse to consume adequate protein intake, and the higher the protein concentration of energy dense the ration, the lower the total DM likely also meets protein requirements. The more the forage meets an adult’s energy requirements, it may be added to soaked forage cubes/pellets to enhance the energy density of a ration.10 Average adult horse crude protein requirements are generally higher in nonstructural carbohydrates. Forage is relatively high in some byproduct feeds (i.e., brans) are more energy dense than forages or other highly insoluble fiber byproducts (Table 1). Although this is helpful when managing the thin senior, keep in mind that as the energy density of the ration increases, DM provision will generally decrease. Furthermore, insoluble fiber, such as cellulose in forages, is slowly fermented by gut microbes and supports a neutral hindgut pH and symbiotic gut microbiota.

Grain byproducts (i.e., brans) have an inverse calcium:phosphorus ratio (Table 1). If presented with a thin senior that cannot properly masticate long-stem forage, consider a commercial senior feed (energy dense and soft texture) and/or combining a cubed or pelleted grass or alfalfa product. Generally, the author’s preference is not to feed alfalfa or commercial products exclusively because these products are highly fortified in calcium and protein, resulting in malodorous stalls and an increased risk for enteroliths. Commercial concentrates such as senior feeds are more energy dense than forages (e.g., 1.2–1.5 Mcal/lb as fed), but are often formulated to be high in fiber to enable them to be fed without forage in the diet. The author prefers to maximize grass forage in the diet. Concentrates are generally higher in nonstructural carbohydrates than forage, which also makes them less than ideal for feeding the PPID senior when insulin sensitivity is reduced. Alfalfa and grass cubes/pellets can be combined or oil (0.7g fat/kg body weight [BW]; e.g., up to 1.6 cup soybean oil for an 1100-lb adult horse) may be added to soaked forage cubes/pellets to enhance the energy density of a ration.10

In addition to calories, it is important to ensure that daily protein requirements are being met. Average adult horse crude protein requirements are 1.26 g protein per BW in kilograms.10 Generally, if the forage meets an adult’s energy requirements, it likely also meets protein requirements. The more energy dense the ration, the lower the total DM intake, and the higher the protein concentration needs to be for the horse to consume adequate protein. For example, if feeding a ration with 0.8 Mcal/lb DM, 1.7% BW in total DM is needed to meet minimum adult maintenance DE requirements (30.3 Mcal/kg BW).10 At this level of intake, the diet would need to contain 7.4% crude protein (CP) DM to meet adult average crude protein requirements (1.26g CP/kg BW).10 Conversely, if feeding a ration with 1.0 Mcal/lb DM, only 1.4% BW in total DM is needed to meet minimum adult maintenance DE requirements and the ration would need to contain 9.0% crude protein DM to meet adult average crude protein requirements. Feeding an enhanced-protein diet may help improve muscle mass in the active senior horse.11

Essential fatty acid requirements of seniors, or any adult horse, is unknown.10 Fatty acids are highly bioavailable and supplementing or enhancing dietary fat will increase the energy density of the ration, which is helpful for seniors that have difficulty consuming enough feed to meet energy requirements. Omega-3 fatty acids are considered essential for other species, but the requirement for horses is unknown. Forage is relatively high in alpha-linolenic acid omega-3, compared with the generally grain-based omega-6 linoleic acid. Dietary omega-3s increases serum eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) concentrations decreases plasma prostaglanding E2, and decreases synovial white blood cell counts in horses.12,13 Omega-3 fatty acids do seem to be clinically beneficial in the face of inflammatory conditions such as chronic lower airway inflammatory disease, but the effect on clinical signs of joint disease has not yet been determined.14 Furthermore, omega-3 fatty acids appear to improve insulin sensitivity in rodents and humans,15 but the applicability to the insulin-resistant senior with PPID has not yet been determined. Although the evidence in favor of enhancing dietary EPA and DHA in a senior’s diet is weak, omega-3s are generally safe. Commercially available omega-3 products marketed for horses are generally not as concentrated in EPA and **Table 1. Forage and Byproduct Statistics**

<table>
<thead>
<tr>
<th>Item</th>
<th>DE, Mcal/lb DM</th>
<th>CP, DM %</th>
<th>NDF, DM %</th>
<th>NSC, DM %</th>
<th>Starch, DM %</th>
<th>Calcium:Phosphorus</th>
<th>Zinc:Copper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grass hay</td>
<td>0.8–1.0</td>
<td>7–15</td>
<td>56–70</td>
<td>8–18</td>
<td>0.5–3.4</td>
<td>0.5:0.2</td>
<td>33:9</td>
</tr>
<tr>
<td>Beet pulp</td>
<td>1.1–1.3</td>
<td>8–11</td>
<td>36–47</td>
<td>4–20</td>
<td>0–3</td>
<td>1:0.1</td>
<td>25:9</td>
</tr>
<tr>
<td>Soy hulls</td>
<td>0.8–1.1</td>
<td>8–19</td>
<td>54–72</td>
<td>2–8</td>
<td>0–3</td>
<td>0.6:0.2</td>
<td>46:9</td>
</tr>
<tr>
<td>Rice bran</td>
<td>1.2–1.7</td>
<td>11–19</td>
<td>15–40</td>
<td>16–34</td>
<td>9–34</td>
<td>2.1:1.7</td>
<td>66:11</td>
</tr>
<tr>
<td>Alfalfa cubes/pellets</td>
<td>1.0–1.2</td>
<td>15–21</td>
<td>38–52</td>
<td>7–13</td>
<td>0.1–4.4</td>
<td>1.5:0.2</td>
<td>24:9</td>
</tr>
<tr>
<td>Wheat bran</td>
<td>1.4–1.6</td>
<td>16–20</td>
<td>33–48</td>
<td>22–38</td>
<td>15–29</td>
<td>0.21:1.1</td>
<td>86:12</td>
</tr>
<tr>
<td>Brewers grain</td>
<td>1.1–1.4</td>
<td>20–31</td>
<td>42–61</td>
<td>2–16</td>
<td>0–14</td>
<td>0.4:0.7</td>
<td>92:12</td>
</tr>
<tr>
<td>Distillers grain</td>
<td>1.3–1.6</td>
<td>22–39</td>
<td>23–41</td>
<td>0–35</td>
<td>0–13</td>
<td>0.1:0.8</td>
<td>58:6</td>
</tr>
</tbody>
</table>

Abbreviations: DE, digestible energy; DM, dry matter; CP, crude protein; NDF, neutral detergent fiber; NSC, non-structural carbohydrates.


Accumulated crop years: May 1, 2000–April 30, 2014.

Mcal = 1000 kcal = 1000 Calories.
DHA as human and cat/dog products. Commercial equine omega-3 products tend to be flavored to enhance palatability; however, some horses will readily consume soft gels when mixed with feeds or soaked forage.

Nutraceuticals
Nutraceuticals are numerous, under-regulated, and understudied. Nutraceuticals often do not contain what the label states and may even contain molecules/compounds not stated on the label.16,17 Evidence of third-party auditing of products and/or manufacturing facilities, such as with U.S. Pharmacopoeial Convention or National Animal Supplement Council, can provide some peace of mind with regard to the product content actually aligning with the label and production quality control. Peer-reviewed published, ideally blinded placebo control, studies provide evidence of efficacy and safety.

For equine joint nutraceuticals, there is some published work. Glucosamine has in vitro anti-inflammatory effects on equine chondrocytes and synoviocytes.18 However, oral bioavailability is low19 and does not seem to improve mobility in senior horses.20 Avocado and soybean unsaponifiables may help protect articular cartilage, but this too does not seem to positively influence mobility in horses.21

A combination of green-lipped muscle, abalone, and shark cartilage reduced joint inflammation in horses with experimentally induced synovitis.22 Green-lipped muscle (25mg/kg BW/d for 56 d) improved mobility in New Zealand horses with fetlock osteoarthritis.23 Cayzer and colleagues23 conducted the double-blinded placebo-controlled study and reported that 67, 63, and 61% of supplemented horses improved by 1 or more scores in flexion, lameness, and pain, respectively. In that study, 40, 35, and 15% of placebo horses also improved by 1 or more scores in flexion, pain, and lameness, respectively. For PPID, chasteberry has been evaluated as a nutraceutical for PPID horses, but the evidence of efficacy is questionable.6,24,25

If an owner wants to try a joint nutraceutical, the author suggests that the veterinarian informs the owner that nutraceuticals are poorly regulated and researched and to purchase products displaying the U.S. Pharmacopoeial Convention or National Animal Supplement Council seal.

Balancing the Diet
Ideally, the goal is to maximize forage, especially grass, in any horse’s diet. Therefore, the author’s general approach to balancing a forage-based senior ration is to either feed a calorie-free low-sodium vitamin mineral supplement (~22% NaCl, ~16 ppm Se) or ration balancer pellet. The latter provides a substrate to top dress oral medications on. When feeding a high rate of a fortified commercial senior feed, vitamin/mineral supplementation is not needed. In general, a horse would need to consume at least 0.5%, and sometimes more than 1% of body weight per day (i.e., at least 5–10 lb of concentrate/d for a 1000-lb horse) in a fortified concentrate (i.e., commercial senior feed) in order to avoid the need to further trace mineral supplementation. However, keep in mind, this is a general rule of thumb and will not apply across all concentrates given that different products have different concentrations of vitamins and minerals.

Feeding Management
How you feed is as important as, if not more important than, what you feed. For the senior with reduced mobility, consider height of water and feed buckets/troughs and distance between feed, water, and shelter.26 Strategies to eliminate any negative effects of competition should be implemented.

Objective(s)
The objective of this “how to” is to highlight that grass forage can be the main-stay of the senior ration, even if the forage form needs to be altered/softened.

2. Materials and Methods
A retrospective analysis of data from our equine teaching herd, since 2008, was conducted. The teaching herd consists of ~20 mares of various breeds maintained on cool-season pasture in groups of 4–7 by body condition score (BCS), with a consideration for social dynamics. The herd is evaluated by the author 4–6 times per year. Rations are built using ideal body weight, adult maintenance nutrient requirements, and forage quality (see Documenting Forage Quality below). For the underweight horse, the author set target BCS to 6/9; for overweight horses, target BCS at 5/9. The author calculated ideal body weight based on the general assumption that each BCS point on a 9-point scale represents approximately 50 lb body weight for a “full-size” 1000-lb ± pound horse. The 50 lb per BCS rule doesn’t apply to all horses, but is a place to start.

Cool-season grass hay was fed when pasture forage is inadequate. Digestible energy requirements were calculated as 30.3kcal/kg ideal body weight for overweight horses and 33.3 kcal/kg ideal body weight for underweight/ideal BCS horses. The amount of grass hay fed was based on energy calculations. In general, 1.5% BW of an average quality grass hay (0.9Mcal/lb DM) will meet the maintenance requirements for adult horses. Forage was balanced with a granular low-sodium vitamin-mineral product. This product was generally available free choice with a minimum target to meet trace mineral and vitamin E requirements for each horse. Horses that lost condition in the winter (~<5/9) were fed a commercially available low starch senior feed (1.5 Mcal/lb as fed). Free-choice white salt is added.
in the summer. Water was available by fence line automatic waterers.

Complete BCS and management records from five senior mares are represented (Fig. 1).

Of our five senior mares, only one (Annie) was thin. The other four senior mares ranged from ideal to obese, with the highest BCS in the fall. KK had tremendous regional fat deposits, especially in the summer months. Fancy had an episode of acute laminitis April 2010. Broadly, the number of obese horses has declined in this herd since the author began managing this herd. Grazing muzzles were instituted the summer of 2012. Before 2012, our only means to control BCS was to take advantage of the winter months of control-feeding hay.

The winter 2009 grass hay was of poor quality (0.78 Mcal/lb as fed [AF]; 70% neutral detergent fiber [NDF] DM) and BCS was lowest for the five senior mares over this winter. Herd care staff increased the hay offered from the original recommendations and observed a high rate of forage waste (roughly 30% or more). The winter 2010 grass hay was of moderate-poor quality (0.82 Mcal/lb AF; 67% NDF DM). Annie’s forage was supplemented with senior feed during the 2009 and 2010 winters. The same moderate-poor quality hay (0.82 Mcal/lb AF; 67% NDF DM) was fed winter 2011. However, a high-quality hay (1.0 Mcal/lb AF; 46% NDF DM) was fed to Annie’s group; Annie was not fed a senior or supplemental feed during the 2011 winter. A different moderate-poor quality hay (0.80 Mcal/lb AF; 67% NDF DM) was fed during the 2012 winter and Annie was supplemented again with senior feed.

Determining Forage Quality

Stage of plant maturity is the single most influential factor on forage quality. There are numerous other factors (i.e., sun, rain, temperature, soil fertility) that also influence forage growth and thus quality. Forage quality can be estimated using olfactory, visual, and tactile senses such as assessing smell (i.e., moldy, fresh), leaf:stem ratio, presence of seed heads, color and texture. A hay with a low leaf:stem ratio and presence of seed heads is more mature and likely to be of poorer quality. Conversely, hay with a high leaf:stem ratio will be softer and have greater nutritional value (i.e., protein, increased digestibility). Hay should also be free of mold (black spots) and foreign debris (sticks, leaves). Hay should be green in color and have a fresh, pleasant aroma (not moldy). The most accurate way to determine forage quality is to evaluate a chemical nutrient analysis of the forage.

Dried forage (hay) is most commonly sampled, but fresh forage (i.e., grass pasture) can be sampled and analyzed as well. For hay (grass or alfalfa hay), 10 representative bales (or 10%) from each batch should be sampled with a hay corer. You can either borrow a hay corer from your local extension office or ask to have an extension agent come to your farm to sample the hay. Check with the forage laboratory regarding sample submission; generally, hay should be shipped dry and fresh forage should be shipped on ice. Select an analysis that provides, at minimum, DE, crude protein (CP), and neutral detergent fiber (NDF).

When assessing forage quality, the author considers the parts of the plant cell, the cell wall, and the
cell contents. The cell wall serves as the skeleton for the plant and as forage matures, the cell wall to cell content ratio increases. As plant biomass increases, quality decreases. A forage quality analysis should include analyses of DE, CP, and NDF. NDF represents the forage cell wall. More specifically, NDF represents cellulose, lignin, and hemicellulose. This fraction is used as a positive indicator of forage bulk. Therefore, the higher the NDF the more bulky the hay and the less a horse is willing to consume. The author generally prefers forage NDF less than 70% DM basis for horses. As forage matures, DE and CP generally decreases while NDF increases.

3. Results

The author recommends monitoring BW and BCS monthly. The herd care staff checked the mares between our evaluations and would notify the author of horses less than 5/9 or greater than 6/9. The general goals and expectations of managing the senior horses were to achieve and/or maintain a BCS of 5–6/9. The first winter (2011) Annie did not require a senior feed to maintain a BCS 5/9 throughout most of the winter. Forage quality determines the need for concentrate.

4. Discussion

Age is not a disease and not all seniors need a special ration. If the senior is in good condition (BCS 5–6/9), is clinically healthy, and the ration is properly fortified, then there is no indication to change the ration. Furthermore, when reaching for special feeds and supplements marketed to the senior horse, do not forget about the basics. The most common cause of death for horses greater than 15 years of age is disease of the gastrointestinal (GI) tract. Although the cause of GI disease is broad, diet and feeding management is a significant factor that influences a horse’s risk of GI disease. The author suggests starting with the forage (pasture, long-stem, cubes, pellets) and building the ration up from there. Feeding a good-quality forage can reduce or prevent the need for commercial concentrates. When more energy is needed, there are several commercial senior feeds, formulated as relatively high-fiber complete feeds, to choose from. When in doubt, contact our Nutrition Service, vetnutrition@vt.edu; 540-231-1775 (phone); 540-231-6448 (fax).

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Virginia-Maryland College of Veterinary Medicine receives food gifts in kind from Southern States.

References


How to Refeed Starved, Malnourished Horses —
A Work in Progress

Rebecca L. Remillard, PhD, DVM, DACVN

1. Introduction

“Hard Times Leaving Animals Homeless”
“At MSPCA (Massachusetts Society for the Prevention of Cruelty to Animals) Nevins Farm, the number of private horse surrenders surged from 21 in 2007 to more than 70 in 2009.” Brian Benson, Boston Globe, January 14, 2010.

“Neglected Horses in Maryland Multiply as Economy Continues to Sag”
“Horse rescue operators are wrestling with a staggering number of horses in need of homes, a byproduct of the region’s crumbling economy, struggling racetracks and the closure of U.S. slaughter plants.” Megan Miller, Capital News Service, March 13, 2009

It is common knowledge that the number of horses with low body condition scores (BCS < 3/9) due to simple (absence of primary disease) starvation have dramatically increased in humane shelters since 2007, yet there is very little information clearly outlining the nutritional rehabilitation plan for the spectrum of such cases. In the worst-case scenario, an adult horse will lose approximately 40% of optimal body weight (BW) due to a complete lack of feed for 60–90 days, and will no longer be able to support itself, become sternal initially, and then laterally recumbent, and then most will die within 72–96 hours if they cannot rise.1,2 Once 40–45% of optimum BW has been lost, survival is unlikely regardless of aggressive treatment. Fortunately, most low-BCS equine cases do receive some fraction of an inadequate diet, often of poor quality, for more than 3–4 months and are presented to humane shelters or rescue leagues before becoming recumbent.3 The objective here is to suggest a nutritional rehabilitation plan for low BCS (1–3/9) horses due to simple starvation-based on initial BCS and laboratory data uncomplicated by primary disease.

2. Materials and Methods

Physical Examination
An immediate and thorough examination of each animal will help to pinpoint the cause of the weight loss and identify any concurrent diseases or preexisting condition. BW should be accurately recorded using a weigh scale as opposed to weight tapes measurements, which, even if performed correctly can be off by ±5% (50 lb in 1000 lb horse). Most starved equine cases occur through the winter months when hair coats are long, dull, and unkempt that tend to mask loss of body fat and muscle; hence, proper BCS determinations and assessment of muscle wasting must be completed using physical palpation. It is
important to remember that BCS is directly related to the body fat content and does not include an assessment of muscle mass. It is presently assumed that horses, similar to other species, at optimal BCS have approximately 15–20% body fat (subcutaneous [SC], intramuscular [IM], abdominal).4 However body fat as percentage of weight may not be linear at low BCS; ie, as BCS decreases, percentage of body fat loses are exponential.5 In the face of decreasing fat stores with continued caloric deficiency, more muscle (skeletal and visceral) is catabolized for energy. Given that the half-life of serum albumin in the horse is approximately 19 days, a low serum albumin in the absence of protein losing enteropathy, renal or liver disease would suggest inadequate feed intake for many weeks.3 Measurement of BW and condition do not provide sufficient evidence of emaciation. Muscle wasting in the absence of fat is a relatively better assessment of malnutrition and extent of suboptimal nutrient intake.6,7 Extent of muscle loss is the primary determinant of survival because without treatment, as seen in several species, a greater than 25–30% loss of body protein compromises cardiac and pulmonary function and is catabolized for energy.2 Hence, when emptied, constitutes 4–5% of BW in a mature horse. Large intestine is the primary site of the equid microbiome digesting most of the dietary fiber and approximately half of the soluble carbohydrate, then absorbs the resulting nutrients, and insensible water and electrolytes.16

Blood Biochemical Evaluations
Knowledge of the laboratory findings in emaciated horses is useful in scoring the intensity of emaciation, and in establishing a prognosis.11 Blood work results (i.e., increased free fatty acids [FFA], glycerol, total lipids, triglycerides [TG], phospholipids, cholesterol, B-hydroxybutyrate, lactate, bilirubin, cortisol, and lower Mg, Ca, K, and insulin) may aid in the determination of the extent and severity of starvation, and in conjunction with BCS, may help with the decision to treat given financial, logistic, and time constraints.10,12,13

If the decision is to initiate treatment, based on initial blood work, the patient should be rehydrated orally if possible; however, IV correction of electrolyte and acid base imbalances (without glucose) may be necessary and should be started before the reintroduction of feed. A parenteral B-vitamin product containing thiamine, riboflavin, niacin, and pyridoxine may be administered at 10–50 mL/500 kg BW in conjunction with IV fluid therapy for 1–3 days to begin repletion of those vitamins essential to energy metabolism.

Feeding Plan
Once the physical examination and laboratory data have been collected and the commitment to rehabilitate and refeed the patient has been made, a feeding plan based on BCS (Table 1). One must resist the human urge to provide these horses with large amounts of hay and grain. In my experience, it was very important to explain specifically to owners, veterinary technicians, barn help, and whomever may have access to the patient, the importance of a slow and methodical reintroduction to feed that must exclude them from feeding the patient any feeds other than the type and amount prescribed. The well-intentioned attendant feeding outside of the prescribed plan may initiate a refeeding syndrome and possible death of the animal. The refeeding syndrome has been well described previously, and so will not be described here other than to say it must be avoided.12,14

Refeed the Gut First
It should be cause for pause when considering the first feed into a compromised small intestine (SI). The SI itself is universally dependent on intraluminal nutrition, and within days of no food, will show evidence of compromise.15 As seen in other species, by day 7 without food, small-bowel weight will have decreased 22%, mucosal weight (−28%), protein (−35%), and DNA (−25%) will be significantly less than day 1; all of which compromises SI function.16 SI atrophy is characterized by decreased villus height and crypt depth, surface area and motility, brush border enzymes, secretions, and immunity with an increased risk of bacteria (including probiotics), endotoxin, and cytokine translocation. Overall, the net effect of not feeding the SI is decreased end-stage digestive enzymes, nutrient- absorptive processes with an increased risk of systemic infection.

Microbiome
Large intestine in a mature horse is composed of the cecum (25–30 L), large colon (50–60 L), small colon (18–20 L) and when emptied, constitutes 4–5% of BW in a mature horse. Large intestine is the primary site of the equid microbiome digesting most of the dietary fiber and approximately half of the soluble carbohydrate, then absorbs the resulting nutrients as released. There is also microbial protein produced, digested, and absorbed from the cecum and colon. Hence, when refeeding a malnourished horse, one must consider careful refeeding of the microbiome initially. You have two patients (host and microbiome) and one cannot survive/thrive
without the other. The microbiome is a very large number and diverse group of microbes, outnumbering the horse itself in terms of total cell number and DNA. Our understanding of the composition and function of this population has been extremely limited but we do know the microbiome is profoundly altered in certain disease states to the detriment of its host. We are only now developing the computational abilities to collect and analyze the data by which to identify species and numbers within the normal microbiome of a horse. The development and increasing availability of next generation sequencing and evolving bioinformatics offer never-before-available tools by which to study the equine microbiome. Probiotics are widely used presently because they are thought to do no harm but we should have a specific end goal in mind when we prescribe a treatment. As such, I believe the use of probiotics at this time to reestablish the microbiome in malnourished horses a waste of dollars better spent otherwise, at least until we know what we are trying to achieve and there are known efficacious products available.

By way of an example on how to reestablish the equine microbiome, foals born with a sterile gut obtain a mature microbiome similar to their mares within the first few weeks of life. The source of microbes is thought to begin during passage through the mare’s vagina, but then maternal contact (nursing, grooming) and exploring behaviors provide contact with bedding, dirt, and feces, etc. Foals preferentially consume fresh over dried feces from their dams. They have also been known to consume pasture, hay, or grain as early as a day old and by week 5 may spend more than 20% of their time grazing or eating nonmilk foods. Therefore, I am suggesting that in the rehabilitation of starved horses, that they be “housed” surrounded by other horses, feeds, dirt, and manure which should be more conducive to replenishing their microbiome as it proceeded once before in their lives as foals, rather than isolated in a frequently picked stall.

Feeding Plan
At this time, it would seem prudent to begin with rations containing less than 20% readily available carbohydrate estimated by nonstructural carbohydrate (NSC) and higher fiber (15–25%), preferably a mix of soluble and insoluble, respectively, to avoid causing the refeeding syndrome and refeed the microbiome. There are several other terms (nitrogen free extract [NFE], water-soluble carbohydrates [WSC], ethanol-soluble carbohydrates [ESC], nonfiber carbohydrates [NFC] starch, sugar) used to describe carbohydrates in rations; however, NSC is a technically accurate term and should be used to compare feeds. Currently the best fiber estimate we have is crude fiber.

Forage Rations
There are only a few studies on the refeeding of starved horses, but feeding high-forage ration first is a common recommendation. The lower the BCS and the greater the muscle loss in patients, the higher the protein level should be in the initial forage fed because it takes protein synthesis to regenerate a full complement of digestive enzymes and serum carrier molecules to transport nutrients from the intestines and liver to other tissues. In general, legume hays contain 18–23% protein with 11% NSC whereas grass hays (timothy, orchard, and fescue) contain 6–14% protein with 19% NSC. A forage-first plan also refeeds the microbiome, which is in turn essential to regenerating gastrointestinal tract physically (mucosa) and functionally (motility) and provides nutrients (energy, protein and vitamins) to the host.

Grain and Concentrates
Grains should be used sparingly during the initial feeding plan as the more debilitated the patient, higher is the risk for the deadly refeeding syndrome, which will often occur within the first 10–14 days due to a sudden increased carbohydrate intake. NSC is highest in grains such as corn (73%), oats (48%), and wheat (66%). In addition, these grains are relatively low in protein (8–13%) and crude fiber (2–9%) and as such are not the best feeds fed initially to starved horses.

The term concentrate generally implies a grain mixed with minerals and vitamins in a pelleted or “sweet” feed form to keep the micronutrients well mixed throughout the feed. Although feeding minerals and vitamins initially to starved horses will help in reviving co-factors and co-enzymes of metabolism, feeding these micronutrients with a grain is not advisable initially, again to avoid a refeeding syndrome. Complete “senior” feeds have been suggested with caution because they may contain more than 20% NSC. Another option might be those complete feeds marketed as “low carb” that report a NSC less than 20%, eg, “lite” feeds with 10% NCS, or “Senior” feeds with a starch + sugar maximum of 20%. Better-formulated and more-specific products for refeeding horses are appearing on the market. These contain high-protein quality ingredients such as alfalfa, soy, and whey, a mix of fiber types (14%) with minerals and some B- and fatsoluble vitamins was designed and tested clinically in hypophagic horses. A powdered product reported containing 11% starch + sugar can be offered for voluntary consumption or tube fed after adding water.

Appetite Stimulation
Assuming there are no contraindications to significant oral feeding such as dental, pharyngeal, or esophageal lesions, feed offered for oral consumption is preferable to tube feeding or parenteral nutrition. In cases with oral lesions that inhibit or decrease
oral food consumption, in addition to treating the lesions and analgesics, offering soft green grass or a mash (a complete low-NSC-extruded pellet soaked in water) may decrease the pain of eating sufficiently to improve intake. Grass pastures on average have 7–23% protein and 6–20% NSC and mostly mixed-grass (MMG) pastures have 11–25% protein and 7–18% NSC and so are appropriate for starved horses as an appetite stimulant. Fever or pain elsewhere may also decrease appetite and in such cases administering antipyretics and analgesics may improve feed intake.23,24

Feeding at least 10–25% of daily requirement using the gastrointestinal tract has been shown (in G. pigs) to significantly decrease SI atrophy, which in turn should promote appetite.25 Offering small amounts (0.1–0.3% BW), removing discarded feed after a few hours, and frequently replacing with a variety of fresh forages is stimulating and palatable to most horses as well as being in the presence of other horses eating. Bran mashes, although popular, alone are not that palatable to horses, and so mixing with oats, barley, or a sweet feed with 1 cup of molasses and 1–3 tsp of salt may improve consumption.

Although some horses will eat lying down, most prefer to be standing and so use of a sling or other upright supportive measures may improve feed consumption. If able to walk, grazing in hand even dried pasture grasses several times a day may improve the horses’ feed intake and attitude, given that some patients prefer to eat from the ground rather than from a hanging bucket, bin or rack.3 Diazepam administered at low dosages IV may induce a horse to consume feed immediately after treatment but only for 15–20 minutes and only if there are no distractions, etc.; hence, it is not advisable. In addition, debilitated horses may become tranquilized and ataxic unless lower dosages are used. Repeated dosing does not produce consistent results and should be avoided in patients with hepatic compromise. Anabolic steroids and corticosteroids do not have an immediate effect but may increase feed intake after several days.26

Psychological Needs

In tempting a partially anorexic or hypophagic horse to eat, satisfying their psychological needs are essential. Horses are a prey species and therefore safety (from harm) and comfort (lack of pain and social separation/pressures) take higher priority over food consumption, and only after the patient feels safe and comfortable, will they consider eating. Oftentimes hospitalizing a patient, although most convenient for the veterinary staff, is sufficiently frightening to inhibit food consumption. Unfamiliar sights, sounds, smells, aggressive (as seen from the horse’s view) human behaviors, unaccustomed to being boxed indoors (limited sight line), all are not conducive to stimulating appetite. In most cases, keeping herd mates together or close but separated to avoid feed competition and allow for measurement of individual feed intake in relatively open spaces is the best situation conducive to appetite improvement.

Tube Feedings

Completely anorectic or severely hypophagic horses may need to be tube fed to meet all or some of its nutritional needs. There are a limited number of feed options: complete feed slurries, homemade recipes, liquid products designed for horses. Each option has disadvantages.22,27,28 There are potentially advantages to include glutamine and soluble fiber into liquid tube feeding product. Glutamine, a conditionally essential amino acid is needed during periods of physiologic stress to stimulate SI DNA synthesis and will increase SI mucosal mass early in recovery.24 Fiber (~5%) modulates intestinal motility, correcting hypomotility, provides intraluminal stimuli to re-establish normal peristaltic action and transit time, and nondigestible bulk to buffer toxins and holds water to minimize diarrhea. It would be advised, therefore, that tube-fed rations contain both of these nutrients.

There are some disadvantages to tube feeding in that horses may become resistant to nasogastric intubation after 4–5 days with mild epistaxis.21 Metabolic disadvantages to tube feeding vs voluntary consumption of the same low-NSC diets have been reported. Adult horses with good BCS consuming a low-NSC feed voluntarily had lower insulin concentrations (P < .05) at 120 and 140 minutes and lower blood glucose levels at 30 minutes postfeeding than similar horses receiving the same dose of feed via nasogastric tube.21,29

Parenteral Nutrition

Although it is possible to meet the daily caloric and amino acid requirements of an adult horse, the technical and financial obstacles are much greater than rehabilitating a patient using oral voluntary consumption or tube feeding and hence rarely implemented in horses under the care of humane shelters or rescue leagues.30,31

Amount and Frequency of a Refeeding Plan

Beginning digestible energy (DE) intake is based on current (not optimal) BW of the patient using the National Research Council (NRC) 2007 maintenance (low voluntary activity) equation: DE Mcal/day = BW _kg × 0.03.32 It is recommended that several transition days be used initially to bring the patient up to this initial minimum DE goal, i.e., 3–4 days for a BCS 3 horse vs 6–10 days for a BCS 1 horse using a low NSC feed (Table 1). In addition, the daily amount of feed should be initially divided into multiple feedings per day, again depending on BCS, i.e., 3 meals/day for a BCS 3 horse vs 6 meals/day for a BCS 1 horse. The amount of feed consumed (feed in – feed out) should be re-
corded and consumption as a percentage BW should be calculated (total kg of feed consumed per day/BW kg) and reviewed frequently in the early phases of rehabilitation. Ration DE, protein, NSC, fat, and crude fiber concentrations are suggested by BCS (Table 1).

**Example:** A 14-year-old mare with BW 314 kg, BCS 2 with moderate muscle wasting.

**Step 1**
An initial daily minimum DE goal would be 9.4 Mcal/day (314 × 0.03), using a 4–6-day transition period to reach that minimum and with each days’ feed total divided into 4 meals/day using a MMG hay (with 2.1 Mcal/kg, 12% protein and 12% NSC) (per Table 1; BCS column 2), the initial feeding plan would be as follows (Table 2).

**Step 2**
If the mare consumed 4.5 kg of hay on day 4 (1.4% BW) and if there were no complications, the daily DE intake should be increased (1.2×) to 11.3 Mcal/day fed in 4 or 3 meals/day depending on her clinical response. So the daily feeding orders at this point would be 5.3 kg MMG hay/day (1.7% BW) divided into 3 meals of 1.8 kg/each.

**Monitoring**
Body weight should be measured weekly using a weigh scale rather than a weight tape. It should be expected that weights may initially decrease or not change during the initial feed transition days to full DE intakes or may increase due to rehydration and increased gut fill.33,34 Hence, it will be several weeks before a pattern of weight gain can be discerned and considered reliable. Minimizing energy losses by attempting to maintain the horse in a near neutral thermic environment and/or use of light

| Table 1. Refeeding Plan for Horses Based on Initial BCS and Laboratory Data |
|----------------|---------|----------|----------|
| Assessment     | BCS     | 1        | 2        | >3       |
| Physical Examination | BW % of optimal | 70% or less | 75 to 85% | 85 to 95% |
| Muscle loss    | Severe  | Moderate | Mild     |
| Lab Data*      |         |          |          |
| CBC            | RBC, Hb, Lympho | Low      | Low      | Normal   |
| Serum bio chem | Proteins     | Low      | Low normal | Normal   |
|                 | Glob alpha 1 | High     | High     | Normal   |
|                 | BUN/Creat    | < 15 mg/dL | Low    | Normal   |
|                 | TG           | Low      | High normal | Normal   |
|                 | FFA          | High     | High normal | Normal   |
|                 | Bilirubin    | High     | High normal | Normal   |
|                 | Alk Phos     | Low      | Low      | Normal   |
| Electrolytes   | Na, Cl, K, Ca, F, Mg | Below or low normal | Low normal | Normal |
| SI integrity   | Poor       | Moderately weakened | Normal   |
| LI microbiome  | Poor       | Moderately poor to normal | Normal   |
| Fluid therapy to correct | Hydration | ✓       | ✓          | prn***   |
| w/o glucose    | Acid base  | ✓       | ✓          | prn      |
| Electrolytes   | ✓       | prn      |
| Refeeding Plan |         |          |          |
|               | Water      | IV stabilization then free choice | IV if needed then free choice | Free choice |
|               | Salt / TM block | IV stabilization then free choice | IV if needed then free choice | Free choice |
| Digestible energy intake goal after transition days | Min DE = 0.03 BW kg × 1.3 after 6–10 d | x 1.2 after 4–6 days | x 1.1 after 3–4 d |
| Meals/d for min DE | 6 meals/d | 4 meals/d | 3 meals/d |
| Consumption (% of BW) | ~1% | 1.5 to 2.0% | 1.8 to 2.3% |
| Ration composition | DE Ration Ranges | 1–4 Mcal/kg DMB** | 2–2.5 Mcal/kg | 2 Mcal/kg | 1.5–2 Mcal/kg |
|                 | Protein     | 8–30% DMB | 18–20% | 10–15% | 8–12% |
|                 | NSC         | 10–50% DMB | 10–15% | 10–20% | 15–25% |
|                 | Fat         | 5–20% DMB | 2–5% | 10–15% | 10% |
|                 | Fiber       | 5–25% DMB | 20–25% | 15–20% | 10–15% |
|                 | BW gain     | 0–1 lb/d | 1–2 lb/d | 2 lb/d |
|                 | Weeks to optimal BCS | 30–40 | 12 to 20 | 4 to 8 |

* After correcting hydration.
** Dry matter basis.
*** As needed.

would be 5.3 kg MMG hay/day (1.7% BW) divided into 3 meals of 1.8 kg/each.

| Table 2. A 14-Year-Old Mare With BW 314 kg, BCS 2 With Moderate Muscle Wasting |
|----------------|---------|----------|----------|----------|
| Target         | Day 1   | Day 2    | Day 3    | Day 4    |
| DE, Mcal       | 2.5     | 5        | 7        | 9.4      |
| MMG hay, kg    | 1.2     | 2.4      | 3.3      | 4.5      |
| MMG hay/meal, g| 300     | 600      | 830      | 1100     |
blanketing when temperatures are below 60°F as needed to help minimize body heat loss but avoid sweating which results in a loss of electrolytes. Repeat blood work (CBC, serum biochemistries with electrolytes) daily is advisable in the first 2–5 days of refeeding expecting resolution of those initial starvation parameters (blood urea nitrogen [BUN], TG, bilirubin) and monitoring for electrolyte shifts (decreasing P, K, and Mg) in those with BCS 1 or 2, and then as needed based on clinical signs. 

Recovering low-BCS horses, if overfed, may have secondary medical conditions such as refeeding syndrome, acute laminitis, diarrhea, and/or colic. Most will have some soft feces initially with refeeding but this should be temporary and in no way dehydrating or debilitating to the patient. Appetite should improve and a subjective improvement in the patient should be noticeable within the first 5 days of refeeding. Monitor and treat pressure sores in recumbent horses to not only minimize pain and discomfort and improve appetite but minimize heat lost through open sores or skin abrasions. Recumbent horses should have deep comfortable bedding available but regularly be encouraged to stand, walk about, graze, and if they should resume recumbency, be it on a different side.

3. Results

There are a limited number of studies available by which to estimate progress in these equine cases. Broad estimates of average daily weight gain and weeks to achieve an ideal BCS of 4 or 5/9 are estimated in Table 1.²,³,¹⁰,¹²,¹³

4. Summary

The objective here was to propose a nutritional rehabilitation plan for low-BCS horses¹⁻³ due to simple (uncomplicated) starvation based on initial BCS and laboratory data to help rescue organizations and shelters assess the resources needed to rehabilitate such a patient. As in medicine, each case is unique. Veterinarians employed by or assisting equine shelters should not hesitate to consult with a veterinary nutritionist, given various case complexities and limited feed options available to some shelter groups may not fit well into this proposed refeeding outline.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References and Footnotes

25. Remillard RL, Guerino F, Dudgson DL, et al. Intravenous glutamine or limited enteral feedings amelioration of small


*Vitamin B Complex 150 Injection, Henry Schein Animal Health, Dublin, OH 43017.

*NCS, nonstructural carbohydrate, which is starch plus sugar content of a feed. This term should not be confused with “low carb” or “low starch” or “low sugar” claims.


*SafeChoice Senior Horse Feed, Nutrena, Minneapolis, MN 55440.

WellSolve W/G, Purina Mills LLC, St. Louis, MO 63166.

William A. Jackson, DVM, MBA, DACVS

Financial statements are readily available and are extremely important summaries of your practice’s overall health. They are uncomplicated to review and underused. These statements give practitioners valuable information from the past, of the present, and for the future. Whether the reports are generated from your office computer or distributed to you by your accountant every 3 months, knowing how to review them is critical for an owner or manager of any practice large or small. Author’s address: WJ Consulting Group, LLC, 16685 Heatherwood Lane, Chagrin Falls, OH 44023; e-mail: WJConsultingGroup@gmail.com. © 2016 AAEP.

1. Introduction
Most of us have the ability to view readily available, unedited financial statements (balance sheet, income statement and cash flow) for our practice but many of us do not take the time to look at the wealth of information they yield. If we do not have a means to readily generate these reports we are all presented final, edited versions of our financial statements at least once if not four times annually from our accountants. Simply looking at the net income at the bottom of the Profit and Loss Statement is grossly misleading. Financial statements contain extremely valuable information that can help practitioners identify internal strengths and weaknesses. By using past data, we have the ability to make economic predictions as they pertain to our businesses. It is the objective of this abstract to define for its readers what each of the financial statements reflects, what conclusions can and cannot be made from them, and how to identify key elements of each statement.

2. Solution
Although valuable information can be extracted from each statement, they provide considerably more information when looked at together. Each statement has its own strengths and weaknesses. The study of all three of the statements provides the practice owner, manager, or associate the tools necessary to properly evaluate the health of the business with very few exceptions.

One of the most commonly used monitoring tools is called trend analysis, otherwise known as horizontal analysis. This method compares the actual dollar amount as well as the percent change over time allowing one to select specific line items within any of the financial statements for comparison. Simple equations are used to make these comparisons.

Dollar Amount of Change = Current Amount − Base Year Amount
Percent Change = (Current Year Amount − Base Year Amount)/Base Year Amount
Examples of each financial statement are included in this report for your reference. The statements are examples of a small business providing veterinary services and having investments in real estate.

The first of the financial statements is the Balance Sheet (Example A in the Appendix). The balance sheet is often considered a snapshot image of the business’s assets, liabilities, and stockholders’ equity at one particular point in time. It is considered a measure of the financial position of the company. Assets are divided up into current and long term. Short-term assets are those that can be converted to cash in less than a year through the ongoing practices of the business. For example, inventory (pharmaceuticals), and cash accounts. Long-term assets include everything else, such as equipment, buildings, land, and vehicles. There is also a segment under assets that reflects depreciation. Depreciation is an entry into the books that lowers the value of the asset over time due to the predicted life expectancy of the asset. The second component of the balance sheet is the businesses liabilities. Like assets, liabilities are divided into current and long term. Current liabilities must be paid within one year. For example, accounts payable and principal payments on loans. Alternatively, long-term liabilities include all other liabilities of the company. An example of a long-term liability would be principal payments on a real estate mortgage. Finally, the third component of the balance sheet, called stockholder’s equity is the difference between the company’s total assets and total liabilities. Simply stated, it represents the net worth of the company.

The next financial statement is the profit and loss, also known as the income statement (Example B in the Appendix). Unlike the balance sheet, the income statement reveals the financial condition of the business over a period of time. It reflects the income (sales) and expenses (costs). All revenues generated by the sales activity of the business are recorded less the cost of the goods sold and the expenses incurred to attain sales of product or service. The difference between sales and costs are considered the business’ net income. Profits are generated when the sales exceed costs. The company incurs financial losses when and if the costs exceed sales. The cost of goods sold (COGS) is the costs of all the raw materials needed to provide a service or produce a good. In most of our cases, COGS reflects the total of inventory items such as penicillin, gentocin, and ketamine. Subtracting COGS from total revenues (sales) equals the company’s gross profit. It is important to recognize that our inventory of medicines is not an expense. Operating expenses consist of items such employee expenses, management fees, and utilities. Subtracting expenses from gross profits yields net income. The income statement provides a good indication of the company’s fixed costs (the cost of operating the business that are not dependent on sales volume) as well as the variable costs (costs of operating the business that vary with sales volume). Depreciation expense is calculated specifically to record the depreciation of assets. If your business owns assets such as a truck, endoscope, or radiographic machine there is a depreciation expense. This expense is calculated by using the asset cost minus the salvage value over the life expectancy of the asset. Although depreciation is the expensing of tangible assets, amortization is the expensing of intangible assets.

The cash flow statement takes information from the balance sheet and income statement to summarize changes in cash flows due to business activity over a period of time (Example C in the Appendix). It represents the cash position of the business and reflects the ability of that business to pay its debts. Cash flow projections are made using the expected cash receipts to schedule payments to suppliers.

3. Discussion
There are pros and cons of each of the financial statements. Although there are a number of conclusions that can be drawn from the information it is also important to recognize a few of the limitations of each statement. For example, the accounts receivable (A/R) balance is itemized in the balance sheet under assets. Without looking into this further, one may conclude that the A/R balance represents expected future income when it may actually reflect age accounts in excess of 120 days that are likely uncollectable. In Example A, under current assets, the company has an unusually high A/R balance of $73,815.22. It would be important to see an aging summary of this line item to determine whether the debts owed the company are collectable. It will also be important to follow the horizontal trend analysis of this line item over time. Is this amount an aberration in the normal activities of the company? Calculating the percent change from last year would provide valuable information to the practice’s ability to collect on accounts. A common mistake made when looking at the income statement (Example B) is putting too much emphasis on the statement and is an indication of the profits earned by the company operations. What many do not realize is that it does not reflect distributions made to owners as compensation if the entity is a limited liability company (LLC), nor does it reflect payments made to the principal of outstanding loans. Therefore, one must look at the net income from the income statement then look for distributions and payments on liabilities found in the balance sheet to recognize the gain or loss of cash. Businesses for which too many draws are being made from or that have an overwhelming debt load might be unsustainable despite high profits. Using the provided examples, Example B indicates a net income of $193,703.10. One must then look back at the balance sheet (Example A) under equity to determine what the dollar value of distributions made to owners is. The example only provides a total of...
$517,405.70 but the breakdown of the line item reveals that the fraction representing owner distributions is $219,682.26. Therefore, although at first glance a business generating $382,137.92 netting $193,703.10 in net income sounds good, the owner is taking too much cash out of the business to be sustainable. Horizontal trend analysis used here would reveal if this was an ongoing trend or if the distributions are unusually high for this period. The excessive distributions have contributed to the loss of $49,724.96 in available cash flows at the end of the period as seen in Example C. In addition, the financial statements allow us to determine the rate of annual growth of accounts receivable and inventory. If these growth rates exceed that of the revenue growth rate, cash is being depleted and is considered unsustainable. Frequent analysis of one's financial statements is one of the most valuable tools available to practice owners to assess the strengths and weaknesses of their business. Statement analysis is not a complicated process but the more one looks at them, the more one will learn and the more comfortable one will be in the information one gleans from them.
Appendix

Example A
Balance sheet as of December 31, 2015.

### Balance Sheet

As of December 31, 2015

<table>
<thead>
<tr>
<th>ASSETS</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Assets</strong></td>
<td></td>
</tr>
<tr>
<td>Total Checking/Savings</td>
<td>35,237.26</td>
</tr>
<tr>
<td>Accounts Receivable</td>
<td>73,815.22</td>
</tr>
<tr>
<td><strong>Total Current Assets</strong></td>
<td>109,052.48</td>
</tr>
<tr>
<td><strong>Fixed Assets</strong></td>
<td></td>
</tr>
<tr>
<td>Land</td>
<td>155,308.00</td>
</tr>
<tr>
<td>Total Building (dep)</td>
<td>712,650.72</td>
</tr>
<tr>
<td>Improvements</td>
<td>249,457.85</td>
</tr>
<tr>
<td>Computers (dep)</td>
<td>1,261.82</td>
</tr>
<tr>
<td><strong>Total Fixed Assets</strong></td>
<td>1,118,678.39</td>
</tr>
<tr>
<td>Other Assets</td>
<td>404,230.97</td>
</tr>
<tr>
<td><strong>TOTAL ASSETS</strong></td>
<td><strong>1,631,961.84</strong></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LIABILITIES &amp; EQUITY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Current Liabilities</strong></td>
<td></td>
</tr>
<tr>
<td>Accounts Payable</td>
<td>4,013.78</td>
</tr>
<tr>
<td>Credit Cards</td>
<td>87,926.31</td>
</tr>
<tr>
<td>Other Current Liab. (LOC, Def tax, CP)</td>
<td>128,936.39</td>
</tr>
<tr>
<td><strong>Total Current Liabilities</strong></td>
<td>220,876.47</td>
</tr>
<tr>
<td><strong>Total Long Term Liabilities (Mort, Loan, -CP)</strong></td>
<td>893,679.67</td>
</tr>
<tr>
<td><strong>Total Liabilities</strong></td>
<td>1,114,556.14</td>
</tr>
<tr>
<td><strong>Equity</strong></td>
<td></td>
</tr>
<tr>
<td>Contributions, RE, NI (less distributions)</td>
<td>517,405.70</td>
</tr>
<tr>
<td><strong>TOTAL LIABILITIES &amp; EQUITY</strong></td>
<td><strong>1,631,961.84</strong></td>
</tr>
</tbody>
</table>
Example B

Profit and Loss: January through December 2015.

**Profit and Loss**

January through December 2015

<table>
<thead>
<tr>
<th></th>
<th>Jan-Dec 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>INCOME</td>
<td>382,137.92</td>
</tr>
<tr>
<td>Cost of Goods Sold</td>
<td>(59,658.66)</td>
</tr>
<tr>
<td>Gross Profit</td>
<td>322,479.26</td>
</tr>
<tr>
<td>EXPENSES</td>
<td></td>
</tr>
<tr>
<td>Advertising, Consultants, Professional fees, Insurance, Payroll, Taxes, Utilities, Rent, office</td>
<td>128,670.92</td>
</tr>
<tr>
<td>Supplies, etc.</td>
<td></td>
</tr>
<tr>
<td>Net Ordinary Income</td>
<td>193,808.34</td>
</tr>
<tr>
<td>Other Income less Expenses (interest income etc.)</td>
<td>(105.24)</td>
</tr>
<tr>
<td>NET INCOME</td>
<td>193,703.10</td>
</tr>
</tbody>
</table>
Statement of Cash Flows
January through December 2015

OPERATING EXPENSES

Net Income $193,703.10

Adjustments to reconcile Net Income
To net cash provided by Operations:

Accounts Receivable -19,590.22
Accounts Payable -1,243.86
Company CC 92,788.19

Net Cash Provided by Operating Activities 265,657.21

INVESTING ACTIVITIES

Building -6,400
Equipment -1,600
Building Improvements -2,000
Computers -1,846.66
Property Purchase #4 99,049.40
Property Purchase #5 108,372.74

Net Cash Provided by Investing Activities -219,268.80

FINANCING ACTIVITIES

Mortgage Property #1 -30,454.32
Private Loan -23,037.34
Member Contributions 20,249.30
Distributions -62,871.01

Net Cash Provided by Financing Activities -96,113.37

Net Cash Increase for period -49,724.96

Cash at beginning of Period 84,962.22

Cash at end of Period 35,237.26
Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.

References
How Much Can I Pay a New Associate?

Jorge L. Colón, DVM, MBA

A detailed analysis of a new associate's expected revenues against a precise forecast of all expected cash flows will allow practice owners to better define the associate's level of compensation that will meet the practice's required rate of return on their investment. Author's address: Jorge L. Colón, DVM, MBA, PLLC, PO Box 11631, Lexington, KY 40576; e-mail: jorgecolondvm@me.com. © 2016 AAEP.

1. Introduction

A clear message inferred from reports on the 2015 American Veterinary Medical Association Report on the Market for Veterinary Education is that the cost of veterinary education is creating a significant financial burden for recent graduates. Although the 2015 national average 4-year cost for education was $103,327 for in-state seats and $192,710 for out-of-state seats, the graduates who filled those seats left school with a mean debt of $132,560 and $187,379, respectively.1 Compounding the financial predicament created by the excessive debt accumulated, these new veterinary graduates entered the workforce in 2015 facing an average debt-to-income ratio of 1.9:1.2

Meanwhile, practicing equine veterinarians continue to face the problems created by the economic recession that started in 2008. Not only do revenues continue to be affected through the competition for service provision within the shrinking pool that is the clients’ dwindling discretionary spending, but the bottom line continues to be adversely affected by the ever-increasing costs of doing business. Making the move to hire a new associate—whether because there is opportunity to grow the practice or because there is a desire by the owner to slow down—is a situation defined by the financial quandary created by the new workforce that will demand more money than they are initially worth to make ends meet, and the reduced money available within the industry. Veterinary business owners need the tools to properly forecast the actual expenses associated with employing a new associate for their specific practice. Only then would they be able to determine the compensation amount that can be offered that would still provide a sound financial decision for the practice through the delivery of the returns required by the investment. The analysis would provide the potential associate with the financial facts that dictate their worth to that specific practice so that they, in turn, could make their own financial decision regarding the practice’s ability to meet their self-created financial needs.

2. Case Example of the Cash Flows Related to Hiring a New Associate

A case example of a new associate hiring project is presented in Table 1. The data presented are based on the high end of the results obtained from the author’s recent, nonscientific survey of members of the American Association of Equine Practice Business Rounds Discussion Group3 together with assumptions that mimic actual data from a private
practice regarding total revenues, gross margins, and costs for overhead. The components of the table are detailed and explained throughout the rest of the document.

### Table 1. Results From Analysis of Survey Responses Together With Private Practice Data Regarding the Investment Opportunity of Hiring A New Associate

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Revenue growth</td>
<td>20%</td>
<td>10%</td>
<td>10%</td>
<td>5%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gross revenue</td>
<td>$169,355</td>
<td>$203,226</td>
<td>$223,549</td>
<td>$245,903</td>
<td>$258,199</td>
<td></td>
</tr>
<tr>
<td>New equipment</td>
<td>($50,313)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salary</td>
<td>57,422</td>
<td>57,422</td>
<td>62,594</td>
<td>68,853</td>
<td>72,926</td>
<td></td>
</tr>
<tr>
<td>Benefits</td>
<td>5,918</td>
<td>5,948</td>
<td>5,977</td>
<td>6,007</td>
<td>6,037</td>
<td></td>
</tr>
<tr>
<td>Health insurance</td>
<td>3,874</td>
<td>3,894</td>
<td>3,913</td>
<td>3,933</td>
<td>3,952</td>
<td></td>
</tr>
<tr>
<td>Mileage</td>
<td>12,164</td>
<td>12,164</td>
<td>12,164</td>
<td>12,164</td>
<td>12,164</td>
<td></td>
</tr>
<tr>
<td>Retirement match</td>
<td>0</td>
<td>1,723</td>
<td>1,878</td>
<td>2,066</td>
<td>2,169</td>
<td></td>
</tr>
<tr>
<td>FICA SS</td>
<td>3,560</td>
<td>3,560</td>
<td>3,881</td>
<td>4,269</td>
<td>4,482</td>
<td></td>
</tr>
<tr>
<td>FICA Medicare</td>
<td>833</td>
<td>833</td>
<td>908</td>
<td>998</td>
<td>1,048</td>
<td></td>
</tr>
<tr>
<td>FUTA federal</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td>42</td>
<td></td>
</tr>
<tr>
<td>FUTA state</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td>275</td>
<td></td>
</tr>
<tr>
<td>Workers comp</td>
<td>230</td>
<td>230</td>
<td>250</td>
<td>275</td>
<td>289</td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td>26,711</td>
<td>29,262</td>
<td>30,623</td>
<td>32,141</td>
<td>33,016</td>
<td></td>
</tr>
<tr>
<td>COGS</td>
<td>51,823</td>
<td>62,187</td>
<td>68,406</td>
<td>75,246</td>
<td>79,009</td>
<td></td>
</tr>
<tr>
<td>Total cash operating expenses</td>
<td>($162,852)</td>
<td>($177,539)</td>
<td>($190,911)</td>
<td>($206,270)</td>
<td>($214,780)</td>
<td></td>
</tr>
<tr>
<td>Net cash flow</td>
<td>($50,313)</td>
<td>$6,503</td>
<td>$25,687</td>
<td>$32,638</td>
<td>$39,633</td>
<td>$43,419</td>
</tr>
<tr>
<td>PV cash flows</td>
<td>$68,815</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NPV project</td>
<td>$18,502</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IRR project</td>
<td>37.92%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Although the new associate’s net cash flow production would be based on the expected revenue generation and the operational expenses that are attributable to the new position, which are discussed below, the practice’s cash flow would be affected, not only by the changes in operational expenses attributable to existing members of the practice plus the net cash flow produced by the new associate, but also by the reduction in the practice’s revenue secondary to the service provision transfer. In all instances where service transfer negatively affects the practice’s overall finances, the acceptance of reduced cash flows and profits must be analyzed by the business owner through the eyes of hopeful improvement in personal and mental health generated by the decreased workload and the increased level of work-life balance.

### 4. Setup and Hiring Expenses

A practice owner will incur expenses because of the new hire even before the associate starts producing

| First Year-Gross Revenue Production | $127,355 to $169,355 |
| Percent of new associate’s first-year gross revenue expected to come from transfer of already existing service provision | 74% |
| Revenue growth Year 1 to Year 2 | 15% to 20% |
| Equipment expense and setup costs | $26,766 to $50,313 |
| First-year compensation | $48,000 to $57,422 |
for the practice. The obvious ones include actual cash outflows for the benefit of the new hire through the purchase and setup costs of the equipment acquired for the associate’s exclusive use. The not-so-obvious ones include the estimation of the value of the already-owned equipment that is transferred to the associate when the owner takes advantage of the opportunity to purchase a new one for his/her own use. Although the cash outflow would not be directly made on behalf of the associate, the estimation of the worth of the equipment handed to the hire is necessary to determine the investment done into the new position; a figure that will be required when performing future financial analysis calculations such as net present value (NVP) and internal rate of return (IRR). Respondents to the survey conveyed that they expected the equipment purchase and setup costs for a new associate to be, on average, between $26,000 and $51,000 (Table 2). During the process of initial analysis, one must not forget to include within the setup costs those one-time hiring-related expenses such as paid relocation expenses. Our case example shows a $50,313 cash outflow for new equipment to set up the associate.

5. Forecasted Associate Expenses

Salary Compensation

Depending on the individual practice owner’s experience, the type of salary compensation style utilized for a new associate has usually been a combination of what they think would work for the practice and what they think is fair based on the income they expect the associate to produce. Neither of these, however, has ever been completely based on factual numbers related to the practice’s current situation or the complete expenses attributable to the position. The goal of this paper is to provide the tools that will help veterinary business owners to more precisely calculate the new employee’s expenses as related to the expected revenue, so that they can more precisely adopt the type of salary compensation style and compensation amount that will better fit the practice based on its financials and intended operations. It is the potential employee’s responsibility to then see if what they are worth to the specific practice will allow them to meet their own financial needs.

An interesting finding from the survey is the wide distribution of compensation styles utilized by the survey’s respondents (Table 3). Although a specific differentiation was not made by the respondents between base salary and base salary plus added production percent, the respondents conveyed that, on average, they expected the new associate’s first-year compensation to be between $48,000 and $58,000 (Table 2). Our case example utilized a $57,422 base salary or 28% of total gross, whichever was higher.

Business Benefits

It is normally expected for veterinary business owners to cover the expenses necessary to allow the associate to provide veterinary services for the practice. Veterinary license, DEA license, continuing education, and mobile phone are some of the most common ones. In addition, other expenses such as travel to meetings (± meals), membership dues, and malpractice insurance are also usually covered. Respondents to the survey indicated that they expected, on average, that these benefits would cost the practice between $3,500 and $6,000 in Year 1 (Table 4). Our case example assumed a 0.5% yearly growth of business benefits.

Table 3. Compensation Style Expected to be Utilized on First Year for New Associates Based on 64 Responses to Survey

<table>
<thead>
<tr>
<th>Compensation Style for First Year</th>
<th>Survey Respondents, %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Base salary or percent of total gross (whichever is higher)</td>
<td>26.6</td>
</tr>
<tr>
<td>Base salary or percent of service gross (whichever is higher)</td>
<td>20.3</td>
</tr>
<tr>
<td>Salary only</td>
<td>20.3</td>
</tr>
<tr>
<td>Base salary plus percent of service gross</td>
<td>12.5</td>
</tr>
<tr>
<td>Base salary plus percent of total gross</td>
<td>10.9</td>
</tr>
<tr>
<td>Base salary plus percent of emergency fees</td>
<td>4.7</td>
</tr>
<tr>
<td>Percent based on production only</td>
<td>3.1</td>
</tr>
<tr>
<td>Percent based on net production</td>
<td>1.6</td>
</tr>
</tbody>
</table>

Table 4. New Associate’s Expected Range of Average Business Benefits, Personal Insurance, Vehicle Mileage Reimbursement, and Retirement Account Matching Based on Responses to Survey

<table>
<thead>
<tr>
<th>Item</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business benefits cost Year 1</td>
<td>$3,544 to $5,918</td>
</tr>
<tr>
<td>Personal insurance cost Year 1</td>
<td>$4,505</td>
</tr>
<tr>
<td>Employer coverage of personal insurance cost</td>
<td>86%</td>
</tr>
<tr>
<td>Expected No. of miles driven in Year 1 by new associate in own vehicle (does not include usage of business-owned vehicle)</td>
<td>23,392 mi</td>
</tr>
<tr>
<td>Mileage reimbursement rate respondents would use for 2016 (federal rate for 2016 is $0.54 per mile)</td>
<td>$0.52 per mi</td>
</tr>
<tr>
<td>Average percent of each retirement contribution made by employee that is matched by employer</td>
<td>86%</td>
</tr>
<tr>
<td>Average maximum cap of employee’s salary compensation that employer matches into employee’s retirement account</td>
<td>3%</td>
</tr>
<tr>
<td>Average start year for employer matching</td>
<td>Year 2</td>
</tr>
</tbody>
</table>
The current laws governing health insurance and employees are too complex for the scope of this paper, especially given that the incorrect implementation of healthcare benefit provision can subject the employer to significant tax penalties under the current Affordable Care Act. On average, the survey respondents indicated that they expected the first-year associate’s insurance expense to be approximately $4,500, with the employer covering approximately 86% of the total cost (Table 4). Our case example assumed a 0.5% yearly growth of health insurance benefits.

Business consults performed by the author have shown that some employers provide associates with the additional benefit of compensation for disability insurance. Although the total expense of this benefit is the same for the employer regardless of to whom the check is written (insurance company or employee), to whom the check is written makes a difference to the employee. If the premium is paid by the employer directly to the insurance company, any disability benefits received by the employee would be considered taxable income. In contrast, if the cost of the premium was paid to the employee as a business benefit, and the employee paid the premium, the money from the employer would be taxable income to the employee but the disability benefits from the insurance company would not be taxable income. To this end, a disability situation would most likely suggest that the employee would be better served through the receipt of nontaxable disability benefits and therefore the employer should provide this business benefit in the way that is most advantageous to the employee.

Vehicle Expense
In an equine practice with an ambulatory component to it, there are two types of situations related to the expected vehicle expense that must be analyzed by each individual practice. The practice can provide a business-owned vehicle to the associate for him/her to practice out of, or it could require the associate to provide their own vehicle and then reimburse him/her for the business miles driven at a rate dictated by the Internal Revenue Service. The use of a business-owned vehicle by the associate places the expense of vehicle ownership, insurance, repairs, maintenance, etc. on the employer and creates no financial situation for the employee.

The use of a personal vehicle by the associate transfers all of the vehicle expenses to the employee, which would be partially offset by the mileage reimbursement paid by the employer. The mileage reimbursement rate for 2016 is $0.54 per business mile. An employer can choose to pay the stated rate, a lower rate if they deem the vehicle is not driven 100% for business purposes, or a higher rate if they want to be generous. Although the mileage reimbursement amount is an expense to the employer, any properly documented mileage reimbursement at or below the Internal Revenue Service (IRS) rate is nontaxable income to the employee (anything paid above the IRS rate would be considered taxable income).

There are advantages and disadvantages to each method and the specifics must be analyzed within the context of each individual practice. Survey respondents who would select to reimburse the new associate for the use of their personal vehicle indicated that they, on average, would pay $0.52 for each of the 23,392 miles they would expect the new associate to drive in the first year (Table 4). This was the method utilized for the case example.

Retirement Plan Contribution
Defined contribution plans are offered by some employers and the contribution, matching, and coverage requirements are dependent on the type of retirement plan used by the business owner. Those employers who provide a matching benefit into an employee’s retirement account usually match a percent of the employee’s contribution up to a maximum and may have a waiting period before the matching commences. Survey respondents indicated that, on average, they matched 86% of each employee’s contribution, with the total matching capped at a maximum of 3% of the employee’s total salary compensation, and started matching on Year 2 of employment (Table 4). The case example used a 6% employee contribution with a 3% employer matching cap starting in Year 2.

FICA and FUTA Taxes
Under the Federal Insurance Contributions Act (FICA), an employer’s federal payroll tax responsibilities include withholding from an employee’s compensation and paying the employer’s portion of the contribution for Social Security and Medicare taxes. FICA requires that an employer withhold 6.2% of the employee’s compensation for Social Security and must similarly pay a matching 6.2% for the employer’s portion (12.4% total). For 2016, this tax is levied on the employee’s compensation level up to an $118,500 wage base limit. FICA also requires that an employer withhold 1.45% of all of the employee’s compensation for Medicare taxes and must similarly pay a matching 1.45% for the employer’s portion (2.9% total; there is no wage base limit). Although an employer is also required to withhold a 0.9% Additional Medicare Tax on an employee’s wages paid in excess of $200,000, there is no matching from the employer and therefore no employer expense associated with this surtax.

Under the Federal Unemployment Tax Act (FUTA), employers are subject to federal unemployment taxes based on various factors. The FUTA tax is a single 6% rate on the first $7,000 of wages paid to each employee for which the tax applies. However, if the employer pays their state unemployment taxes by their due date, a claim can be made for 5.4% of the federally taxable wages, effectively...
reducing FUTA to a 0.6% tax. The rate for state unemployment taxes are state dependent and some states require withholding for unemployment taxes on employees. General tax rates by state information is readily available, but to properly calculate federal and state unemployment taxes for one’s specific situation, a CPA and/or tax advisor should be consulted. Our case example utilized Kentucky’s state rate of 2.7% applied to the first $10,200 of wages.

Workers’ Compensation
Workers’ compensation is a disability compensation program that serves to mitigate the financial burden resulting from workplace injury. The rate paid by the employer is dependent on the state where the practice is located and on each practice’s individual situation given that the rate paid can change based on the business’ workplace injury history. Our case example used a 0.4% rate.

Overhead
Aside from cash flows for interest and debt, a practice’s cash outflows can be divided into four easy-to-understand classes: there is a cash outflow for the salary compensation of those who produce revenues for the practice, there is a cash outflow for the benefits paid out and the expenses incurred on behalf of those who produce revenues for the practice, there is a cash outflow for the inventory and outside services utilized during the production of revenues, and there is a cash outflow for the overhead expenses that cover all of the systems and personnel the practice puts in place to aid in the production of revenue.

The new associate’s expenses for the first two classes can be easily defined and calculated being that they are straightforward. The associate’s share of the overhead expense, though, is one that is often missed or not properly calculated when analyzing the net cash flow expected from the associate’s service provision. The author has found that an activity-based costing (ABC) system is the truest, most honest, and most accurate way to distribute the share of overhead among the revenue-producing entities in the practice. An ABC system improves the ability to estimate the cash flows associated with a specific project by separating costs into activity cost pools and identifying a cost driver for each pool. In essence, the practice’s overhead costs can be assigned to the practice’s different revenue-producing activities in accordance with the portion of the overhead costs consumed by each activity. A cost driver can be identified for each of the defined activity cost pools and the overhead costs can then be allocated to each of the revenue-producing services in proportion to the amount of the cost driver consumed by each service (See Appendix I for a case example).

A generic method of applying ABC to an equine practice’s overhead is to identify total overhead as the activity cost pool and each dollar of revenue as the cost driver. In this manner, each dollar of revenue will carry a portion of the overhead expense as dictated by the percentage of total overhead expense against total revenues. If, for example, a given year’s total overhead was 25% of revenue, then each dollar of revenue would carry $0.25 of overhead expense. The actual calculation of overhead expense against each dollar of revenue will be more precise the more detailed the overhead expenses get assigned to the different sources of revenues. Business insurance, for example, would be an overhead cost that would be equally assigned among all sources of revenue given that they all would consume this cost at the same rate, but overhead costs associated with the veterinary technician should be assigned based on the consumption of that cost by the different sources of revenue (revenue from radiographic procedures, where the assistant is utilized, would consume a high cost whereas revenue from external laboratory work would consume a low cost). The end result of this process is a more precise estimation of the portion of the practice’s total overhead expense that should be attributed to the new associate’s production.

Our case example utilized a practice’s total overhead of $55,133 that grew by 1% yearly. The associate’s portion for each year was calculated as the total overhead times the associate’s revenue as a percent of the practice’s total revenue.

Cost of Goods Sold
In veterinary medicine, the cash outflow for the inventory and outside services utilized during the production of revenues corresponds to the practice’s cost of goods sold (COGS). Analysis of the practice’s financials should precisely indicate the business’ gross margin during the past several years, which would suggest the practice’s running COGS. Just like with overhead expenses, the amount of COGS consumed by the associate’s revenue production should be an expense considered when evaluating the position. If the new associate’s range of service provision will mimic that of the general practice, then the practice’s gross margin can be utilized to calculate the COGS related to the new associate’s projected revenues. Our case example assumed the associate’s service provision to mimic the practice, which carried a gross margin of 69.4% resulting in apportioned COGS that were 30.6% of revenues.

If, on the other hand, the new associate’s service provision will not mimic that of the general practice, a more precise assignment of COGS can only be achieved through an ABC system as previously described for use in assigning overhead. Different subdivisions of the revenue generation can be created based on their utilization of COGS. The COGS within that subdivision would be the cost pool and the revenue generation within that subdivision would be the cost driver for that pool. Different cost pools within the service provision can be established based upon each pool’s utilization of cost of...
For example, physical exams and rectal palpations should have low cost of goods associated with them, whereas blood work and ancillary testing should carry a high cost of goods. These two scenarios would require COGS to be applied at different rates of COGS expense against each dollar of revenue. To this end, different cost pools should be created for the different classes of revenue as dictated by the cost of goods that goes with each class. Each dollar of revenue within each pool would still act as the cost driver but each one would carry the cost of goods associated with that revenue pool (see Appendix 1 for a case example).

Although the differentiation of revenues into different subdivisions depending on the cost pool being estimated will significantly increase the complexity of the data preparation for financial analysis, the increase in precision obtained through better separation of data will not only significantly improve the accuracy in assigning overhead costs and COGS against each dollar of revenue, but it will ultimately serve as the platform needed for a previously described method of determining the price for a procedure. And, as the example in Appendix 1 shows, a more precise analysis can better define the profitability of each revenue center so that service efforts and attempts at business growth can be directed and implemented more appropriately.

6. How Much Can I Pay the New Associate?

With the information previously detailed, the business owner should be able to generate a complete forecast of the expenses expected to be incurred on behalf of the new associate during the process of setting him/her up for practice and during the first year of employment. The ability to compare the expected revenue production against the more precise calculation of the expected expenses will create a framework that can be used to decide on a salary compensation amount so that service efforts and attempts at business growth can be directed and implemented more appropriately.

Present Value of Cash Flows and Net Present Value of the Hiring Project

The forecasted revenues and expenses, including compensation, will produce a net cash flow for each of the five forecasted years as detailed in our case example. Using a discount rate equivalent to the business owner’s risk-adjusted required rate of return for an investment (25% required rate of return for our case example), the value of each future cash flow can be brought back into today’s dollars, a concept better known as discounted cash flow analysis (Appendix 2). By subtracting from this estimated present value of future cash flows the cash outflow for the original investment associated with the setup and hiring expenses, one will arrive at the net present value (NPV) of the hiring project. If this value is equal to or greater than zero, the cash flows produced by the hiring will equal or surpass those that would be produced by the required rate of return and the hiring project should therefore be seen as an attractive investment opportunity. Our case example provided a present value of future cash flows that exceeded the initial cash investment, thereby producing a positive NPV of the Project, making the hiring decision an attractive investment opportunity.

There will be cases in which the NPV of the project will be negative. The only ways to try to mend this issue during the forecasting process are to reduce the projected outflow expenses (including salary compensation), increase the projected revenue inflows, and/or reduce the required rate of return. If an honest manipulation of these expectations still does not provide a positive number for the NPV of the project, then hiring a new associate would not be a sound financial decision.

Internal Rate of Return

An internal rate of return (IRR) analysis uses the project’s initial cash outflow and future cash flows to calculate the discount rate that will result in a zero NPV for the hiring project. A computed IRR that exceeds the owner’s required rate of return suggests, just like a positive NPV of the project explained above, that the hiring project should be viewed favorably. In our case example, as expected from the positive NPV of the Project obtained, the project’s IRR of 37.9% exceeded the required 25% rate of return.

The exact amount of salary compensation that can be offered, that meets the owner’s required rate of return, can be arrived at without the need for trial-and-error calculations by using the Solver data analysis tool on Microsoft Excel. Given that the project’s NPV will be zero when the project’s IRR equals the required rate of return, one can set Solver to analyze for the salary compensation amount variable that will provide the desired IRR result.

7. Analysis of the New Associate Hire Case Example

Using a risk-adjusted required rate of return for an investment of 25%, the NPV and IRR of the project were around $18,500 and 38%, respectively (Table 1). By definition, the obtained results suggested the hiring of the associate to be an attractive investment opportunity.

A significant observation from the analysis was that, whereas a previously published article suggests that a generic employee’s cost (base salary, employment taxes and benefits) is typically in the 1.25–1.4 times the base salary range, the new veterinary associate’s expense-to-salary ratio hovered between 1.88 and 2.01 for our case example (Table 5). The primary sources for this significance seem to be the ABC application of COGS and overhead.
expenses to the employee and the substantial expenses incurred by the employer associated with mileage reimbursement in an ambulatory setting.

8. Conclusion
The improved methodology for calculating expenses provided by this paper, specifically the implementation of an ABC system for a more accurate assignment of shared expenses, should allow for a more precise forecasting of the cash flows expected to be generated by the hired associate. Based on the owner’s financial return requirements, the exact salary compensation and style that will deliver this requirement can be determined so as to provide the potential associate with a best-case scenario that is still a sound financial decision for the business. Although business owners should do their best to support the professional and financial needs of our new colleagues, new associates should not expect their financial situation to be subsidized by the shoulders of existing practices. In any well-run business, business decisions should be made for the primary benefit of the practice’s equity and debt holders. And as the high expense to salary ratio of our case example shows, the high overall cost of the associate’s position makes it difficult to provide a high salary compensation that will completely satisfy the new associate’s desires. Prospective associates should perform their own analysis regarding the viability of that specific practice’s job offer to meet their personal financial needs.

A hiring project that provides a positive NPV and an IRR equal to, or greater than, the owner’s required risk-adjusted rate of return will present an attractive investment opportunity for the practice that will provide the basis for a sound financial decision. The conclusion that the investment opportunity is an overall sound decision, however, will be dependent on the owner’s ultimate combination of financial and nonfinancial goals. Any acceptance of an unfavorable investment opportunity, as presented through a reduced rate of return, must be seen through the eyes of financial compromise delivered by the reduced workload for the owner and, hopefully, the increased level of work-life balance that the reduced workload should provide.

Appendix 1
Case example of activity-based-costing (ABC) implementation for assigning cost of goods sold (COGS) and overhead (OH) based on fictional numbers and percentages. Practice’s revenue = $500,000, COGS = 35% of revenue and overhead = 20% of revenue. When certified veterinary technician (CVT) is differentiated from fixed OH, OH = 14% of revenue and CVT expense = $30,000 = 6% of revenue. Total neonatal work carries a 61% COGS and

| Table 5. Expense to Salary Ratio of New Associate’s Position |
|----------------|----------------|----------------|----------------|----------------|----------------|
|                 | Year 1 | Year 2 | Year 3 | Year 4 | Year 5 |
| Associate’s cost, $ | 111,029 | 115,352 | 122,505 | 131,024 | 135,771 |
| Associate’s salary, $ | 57,422 | 57,422 | 62,594 | 68,853 | 72,296 |
| Expense-to-salary ratio | 1.93 | 2.01 | 1.96 | 1.90 | 1.88 |

| Table 6. Generalized Activity-Based-Costing Implementation for Assigning Cost of Goods Sold and Overhead Expenses to Different Revenue Generation Subdivisions Within the Practice |
|----------------|----------------|----------------|----------------|----------------|----------------|
|                 | Neonatal Work | Mare Work | X-Ray Work | General Work | Total |
| Revenue, $      | 22,750        | 68,650     | 47,500      | 31,100        | 170,000 |
| Generalized ABC COGS (35%), $ | 7,963 | 24,028 | 16,625 | 10,885 | 59,501 |
| Generalized ABC Overhead (20%), $ | 4,550 | 13,730 | 9,500 | 6,220 | 34,000 |
| Net ABC cash flow before other expenses, $ | 10,237 | 30,892 | 21,375 | 13,995 | 76,499 |

| Table 7. Detailed Activity-Based-Costing Implementation for Assigning Cost of Goods Sold and Overhead Expenses to Different Revenue Generation Subdivisions Within the Practice |
|----------------|----------------|----------------|----------------|----------------|----------------|
|                 | Neonatal Work | Mare Work | X-Ray Work | General Work | Total |
| Revenue, $      | 22,750        | 68,650     | 47,500      | 31,100        | 170,000 |
| Detailed ABC COGS, $ | 13,878 (61% of rev) | 13,730 (20% of rev) | 1,805 (3.8% of rev) | 10,885 (35% of rev) | 40,298 |
| Detailed ABC Overhead (14% of revenue), $ | 3,185 | 9611 | 6650 | 4354 | 23,800 |
| Detailed ABC CVT ($30,000), $ | 3,000 (10% of CVT) | 4,500 (15% of CVT) | 9,000 (30% of CVT) | 1,866 (CVT is 6% of rev) | 18,366 |
| Net ABC cash flow before other expenses, $ | 2,687 | 40,809 | 30,045 | 13,995 | 87,536 |
uses 10% of the CVT, mare work carries a 20% COGS and uses 15% of the CVT, and radiographic surveys carry a 3.8% COGS and use 30% of the CVT. Associate’s projected revenue = $170,000 of which $22,750 come from neonatal work, $68,650 from mare work, $47,500 from radiographic surveys, and the remainder $31,100 mimics the practice’s general operations. The resulting net cash flow after the generalized ABC implementation for assigning COGS and OH can be seen in Table 6, and the results after a more detailed ABC implementation can be seen in Table 7.

**Appendix 2: Formulas**

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<thead>
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<td>Present value of future cash flows (CF =</td>
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<td>cash flow; rate = discount rate)</td>
<td>$\text{CF}<em>{\text{year}}/(1 + \text{rate})^t +$ $\text{CF}</em>{\text{year}}/(1 + \text{rate})^2 +$ $\text{CF}_{\text{year}}/(1 + \text{rate})^3 \ldots$</td>
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<tr>
<td>Net present value of cash flows (NPV)</td>
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<tr>
<td>Internal rate of return (IRR)</td>
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**References**


**Acknowledgments**

**Declaration of Ethics**

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**

The Author operates a veterinary business consulting firm.
How Will a New Hire Affect My Practice’s Finances?

Jorge L. Colón, DVM, MBA

The percent of the new associate’s revenue generation that is a transfer of existing service provision will have a significant effect on the practice’s finances, to the point that revenues from new service provision may lag the increased expenses associated with the new position, thereby reducing the practice’s cash flow available for the owners. Author’s address: Jorge L. Colón, DVM, MBA, PLLC, PO Box 11631, Lexington, KY 40576; e-mail: jorgecolondvm@me.com. © 2016 AAEP.

1. Introduction
The reasons to hire a new associate are practice dependent but are usually related to a need for practice growth or a desire for someone within the practice to slow down. Regardless of the reasons, the financial implication of making a new hire must be analyzed, not only to evaluate whether the new associate can generate an adequate return for the practice owner’s investment into the position, but also to determine the effect that the new hire will have on the finances of the rest of the practice. The practice owner would then be able to review the financial results in light of the personal reasons for the hire.

Based on existing financial data and knowledge of the practice, a practice owner should be able to forecast a 5–10-year period of expected revenues and cash outflows for the original practice, and should be able to forecast the net cash flows for the new associate position based on the position’s expected revenue production and associated expenses. The end result should be the ability to forecast equity cash flows for both the original ongoing practice and the new practice had it hired the associate. Equity cash flows are utilized for simplicity given that they are those that do not include cash inflows or outflows related to interest or debt, and represent the cash available to the owners of the business. If one were to utilize the practice’s cost of equity (the owner’s expected compensation for owning the practice and bearing the risk of owning the practice) as the discount rate for the performance of a discounted cash flow analysis, the present value of the estimated future cash flows can be calculated for both scenarios; a process that would provide a simple discounted cash flow valuation of the equity of the original practice and of the new practice had it hired the associate.

2. Forecasting the Original Practice
Data regarding the practice’s revenue, gross margin percentage, operating expenses related to employee and employer benefits, and operating expenses related to overhead should be available through studying of the practice’s financial statements. Analysis of these statements should provide information regarding the growth trend for each line item. The combination of the above should allow for the forecasting of the expected
cash flows not associated with interest or debt for the original practice. Utilizing the practice’s cost of equity as a discount rate (the author uses 10.41% for most of his analysis), one can then find the present value of the expected future cash flows, thereby arriving at a simple valuation of the practice’s equity (Appendix). The case example presented in Table 1 shows the forecasted equity cash flows of an existing practice for a 6-year period (the cash available to the owner of the practice after all cash expenses have been incurred). In essence, the calculated present value of future cash flows implies that to achieve a 10.41% rate of return for that 6-year period, the practice’s equity is worth $520,351.

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<th>Year</th>
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Table 1. Present Value of a Practice’s Equity Cash Flows for a 6-Year Period

3. Forecasting the New Associate’s Net Cash Flows
Based on individual practice knowledge, a practice owner will have to make a projection of the revenue expected to be produced by the new associate and the growth pattern of this production over the forecasted period. If one assumes that the new associate’s service provision will mimic that of the original practice, expenses associated with cost of goods sold (COGS) and overhead expenses can be assigned based on a percent of revenue as dictated by the original practice’s financials. Expenses for salary compensation, business and personal benefits, vehicle provision or mileage reimbursement, retirement contribution matching, FICA and FUTA and state unemployment taxes, and for worker’s compensation should also be calculated for the new position, and each line item’s growth trend over the forecasted years must be defined. By deducting the forecasted expenses from the forecasted revenues, one will arrive at the expected net cash flow that would be contributed by the new associate to the practice in each of the forecasted years.

4. Changes to the Original Forecast
Respondents to a recent nonscientific survey of members of the American Association of Equine Practitioners Business Rounds Discussion Group expressed that on average they expected that 74% of a new associate’s production would come from the transfer of already-provided service by the original practice. This means that the original practice’s forecasted revenue for Year 1 would have to be reduced by the amount transferred to the associate. The forecast exercise would now dictate that the expected revenue growth used for the original practice would have to be applied to the new, lower expected revenue production by the practice after taking into account the revenue transfer to the new associate. In addition, the assigning of COGS and overhead expenses to the practice would essentially represent the left-over expenses from the practice’s total expense for each line item after taking into account the shared portion assigned to the new associate. The forecasting of expenses for existing employee and employer benefits should, in theory, remain unchanged from that which was originally calculated. Lastly, each yearly cash flow projected for the practice would need to be adjusted by the yearly net cash flow forecasted for the new associate, so that the total practice’s equity cash flow can be obtained for each of the forecasted years. The obtained results will allow for a comparison between forecasted cash flows for the practice that has hired the associate and the original one. Furthermore, the present value of the estimated future cash flows for the practice with the associate can be calculated using the previously defined discount rate, allowing the owner to observe the change in the overall practice’s equity value based on the hiring of the new associate.

Table 2 shows the forecasted equity cash flows for the practice based on a reduced amount of revenue production after transferring of service provision to the new associate who started in Year 2 and for whom an equipment purchasing cash expense was incurred in Year 1. After adding the incremental equity cash flow provided by the associate’s service provision, we arrive at the new practice’s overall equity cash flow and the present value of those cash flows based on a 10.41% required rate of return.

The reason why the new practice’s forecast must be performed based on two different parts is because not only will the expected revenue growth differ between the new associate’s production and that of the original practice, but the assigning of COGS and overhead expenses might differ between both entities if the associate’s service provision were not to mimic that of the general practice. The separation of data enables the generation of a more precise forecast of cash flows for each of the practice’s parts, which in turn provides a more precise valuation of the total practice’s equity.

5. Expected Results
The percent of the associate’s service provision that constitutes a transfer from the practice will have a significant effect on the resulting present...
value of cash flows for the practice given that transfer of revenue generating opportunities reduces the original practice's revenue production. Although the assigning of expenses related to COGS and overhead to the practice will be lower based on the sharing of these expenses with the new associate, the expenses related to the original practice's employee and employer benefits will most likely remain unchanged. The end result is that the practice's overall expenses get reduced at a lower rate than its revenues, and therefore the practice's resulting equity cash flow becomes a lower percentage of revenues when compared with the percentage that the original practice would have generated.

Compounding the issue of the reduction in cash flow production by the practice is the fact that the new associate's expenses compared with the position's revenue generation, will be greater than the ratio of expenses to revenue generation expected from longer standing veterinarians within the practice. Although scenarios will be presented in the initial years in which the new position contributes a positive net cash flow to the practice, the amount provided will most likely fail to counteract the increased cash outflows related to having the new position.

### 6. Conclusion

Although a financial analysis for hiring a new associate might provide evidence that the hiring offers an attractive investment opportunity for the practice, this opportunity must be additionally analyzed based on the effects that the new hire will have on the finances of the rest of the practice. The percent of the new associate's revenue generation that is a transfer of existing service provision will have a significant effect on the practice's finances. After doing the hire, the higher the percent of the associate's revenue generation that comes as a transfer of service, the greater that the practice's total cash flows will lag the cash flows that would have been produced by the original practice. Proper revenue growth of the new associate's position should enable the reversal of this financially unsound scenario. The calculation of the present value of future cash flows will be the measurement that will define whether the hiring is a sound financial decision. Although the initial years' cash flows will most likely be reduced in the practice, an increase in cash flows in future years could effectively make the net present value of all of the cash flows be worth more than the cash flows that would have been produced by the original practice. Ultimately, the practice owner must weigh the financial results of the analysis against his/her reason for wanting the hire in the first place.

### Acknowledgments

**Declaration of Ethics**

The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**

The Author operates a veterinary business consulting firm.

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Appendix: Formulas

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References

Taking the Plunge Into Practice Ownership: Lessons Learned

Wynne A. DiGrassie, DVM, MS, DACT

There is a lot that goes on behind the scenes that you never see as an associate or student to start a practice and make it successful. You should never assume you can always run a practice better, and be prepared to make mistakes and grow from them to become successful. Author’s address: Mountain View Equine Hospital, PC, Steeles Tavern, VA 24476; e-mail: mtviewequinehospital@gmail.com. © 2016 AAEP.

1. Introduction
No matter whether you decide to start practice ownership straight out of school or later in your career, it is a large undertaking but well worth the struggle in the end. My husband and I, like a lot of associate veterinarians, thought we could run a business better than our boss and decided to leave the comfort of a steady paycheck for the uncertainty of ownership. We felt confident we could reinvent the wheel better and learned a lot of valuable lessons over the past 13 years that helped our practice go from the brink of closure to back in the black!

2. Lesson 1: “Don’t Build the Taj Mahal in Rural Southwestern Virginia”
We made the mistake of building bigger than the area could support initially. It was not because the demographics could not support the clinic but because the horse owners were not used to all the bells and whistles. It took years to start to convince people to use new techniques and new tools. The biggest mistake was installing a magnetic resonance imaging machine too soon right before the recession hit. Even though we did get a good deal on the unit, in our area of the country it is still not paying for itself. We have grown the service through time and education.

Things to Consider

1. When starting to either build a facility or even just set up an ambulatory truck, do your homework. Sometimes there is no veterinarian in the area because all the past veterinarians have gone bankrupt in that area and the economy cannot support an equine-only veterinarian.
2. Do not expect all horse locals to be able to support a clinic that will have all the bells and whistles. Even if an area can support the technology, do not assume they will. You will need to educate them over time the benefit of what you have to offer as will be discussed later in this article.
3. If the area you have to settle in is such an area, just remember it is better to start off small and grow with your clientele then start big and go bankrupt. Go to your county government center and local extension office to determine the demographics of the
area. Also ask local businesses that may service the horse community. They will give you some invaluable advice as to what the area can support.

3. Lesson 2: “Love thy Paperwork”
No one ever prepares you for the amount of paperwork that is involved in setting up a business. There are permits and hoops to go through to start a facility and licenses to apply for to even begin an ambulatory practice. You need business licenses, documents of incorporation, Drug Enforcement Administration (DEA) licenses, inspections and approvals from your board of veterinary medicine, radiograph machine inspections, badges, and the list goes on. It took more time and money than we originally expected. Also, never expect your facility to be done on time. We had the monsoon of the century while our clinic was being built, which set us back 6 months from opening the doors, which is a long time to go without income. We had to improvise to get through it by starting certain services early before completion.

Things to Consider

1. Contact the board of veterinary medicine and county government center as soon as you start to think about opening a business. They can help guide you through the paperwork you need to get started.
2. Be prepared to spend more initially than expected: approximately 10% more because you never know what the county might throw at you next.
3. Plan for setbacks and be prepared before you stop generating that steady paycheck and save, save, save for that rainy day. I would try to save enough to cover your bills for 6 months before venturing out on your own.

4. Lesson 3: “The Internet is Your Friend”
Let’s face it: we all want all the new fancy toys with all the bells and whistles, but those toys add up in price and just may not fit into your budget. When we started our practice we knew there were certain pieces of equipment we had to have to run a full-service hospital. We began looking all over at the costs and were sticker shocked. When we figured out we just could not afford that new $50,000+ arthroscopy unit we started looking online. I was surprised to find all the refurbished equipment online. We got a very nice Dyonics system complete for only $5,000. Now I will say be aware and read the fine print because you do not want to buy something that is not in working order or has not been refurbished. We ended up buying a lot of equipment off the Internet to start our business and saved thousands of dollars and most of our equipment has lasted 10 or more years. If you do not like the exact item go to their online store or other items they sell. This is how we contacted a couple of used equipment dealers that found exactly what we needed.

Things to Consider

1. Looking online can save you a lot of money when looking to buy certain high-priced pieces of equipment.
2. Buyers beware. The lesson here is that you can find a lot of great stuff cheaper online but read the fine print and do your homework. Make sure the equipment is in working order and comes with a return policy if it arrives nonfunctional.
3. It is important to research if you can still find someone to fix the unit. Also, if there are disposables needed, make sure they are still available. Contact the manufacturer for that information.

5. Lesson 4: “Let’s Make a Deal” Is Not Always the Right Deal
Ever wish you could go back in time and get a do-over? We all have those moments where you are in the halls of the American Association of Equine Practitioners trade show and the deals they start to tell you about that new product seem too good to be true, and sometimes they are. Do not get sucked in by the vaccine deal that allows you to get 3000 doses of vaccine and not pay for them until April and making four easy monthly payments unless you know that come April you will be able to shell out the money in a lump sum of $5000 or more for that big order and you can sell all of it. Also, watch startup practice deals on drugs and supplies. We did the startup deal and they made all sorts of recommendations as to what you will need and how much. It sounds great when you are a new owner and do not have a clue what to order, but I can tell you I still have more activated charcoal then I will ever use in a lifetime.

Things to Consider

1. It is always better to start off with small orders and the drugs you know you will use a lot of and be able to use all of before the expiration date.
2. If you do not have a clue what you may need then phone another colleague that you can trust to advise you on what to order.
3. Deals are great at these trade shows but make sure you have the cash to back it up. Budget for those monthly payments that need to come out of the account 4–6 months from now.
4. Make sure you can sell most of the product you buy within 6–9 months. If you cannot, consider setting up an online pharmacy through your distributor and link to your Web
site to handle those nonessentials your client may want.

6. Lesson 5: “If You Build It, They Will Come”
The Field of Dreams does not exist without hard work. You cannot expect to build a state-of-the-art facility and for people to just walk in and start using your services right away. You do need to advertise. When we first came to town none of the veterinary hospitals in our area advertised. It was taboo. I grew up in the restaurant business and I knew the importance of advertisement and began with print advertisements in local horse magazines. We also did feature advertisements during breeding season showcasing our stallions. I wrote articles for local horse journals on a monthly basis about health care, gave seminars at every little group there was, and set up booths at events and horse shows. The funny thing is that the other clinics started to follow suit and now lots of veterinarians in our area advertise. It started to pay off and then it took off, not with more advertising but by word of mouth from happy clients. The word on the street then took over as more people wanted to come to us to fix their horse because we fixed Mr. Smith’s horse down the road.

Things to Consider

1. Advertising is essential with any new business. Write articles and blogs, handout cards at events, and give away hats or shirts with your name and logo.
2. Offer to speak to local horse groups and get their email addresses. You can then send out electronic newsletters, blogs, etc.
3. Nowadays social media is the best way to get the word out rather than print advertisement. Start a Facebook page, Web site, twitter, etc. to help people find you and help you educate your clientele.
4. If you like to trail ride, show horses, or just even go watch, go. The best way I have found to get clients is to socialize on their turf—horse shows. We now have clients come from out of state because of our commitment to the horse showing industry.
5. If you do not want to show, offer to be the veterinarian for a show for free and make sure to show up and socialize. Trust me, it works.

7. Lesson 6: “Know When to Say When”
Read my lips: You are not a lending institution. In the equine field it is hard to collect for services rendered. Why? A lot of times it is because the owner is not present at the boarding/training barn, and second, we do not like to talk money without fear of offending someone. Have you heard the line, “It’s my daughter’s favorite horse!” or “We just had major medical expenses,” etc....? I will admit it tugs on the heart strings because we truly got into this business for the love of the animal. We learned the hard way just like a lot of new veterinarians. At one point we had more than $150,000 in accounts receivable and were close to bankruptcy even though we were still fairly busy. We had to make some tough decisions in our practice and a few clients left, but now we gross just as much, net more, and work fewer hours. The first thing I did was get two solid employees to work the front and back of the clinic. The receptionist has her sweet southern charm but while she is sweet talking you, she is also getting that credit card number before we even go to the farm. Our account collector works part time for us and her main job is a medical bill collector, which is the best type of person to have in this position. She has the best way to get people to at least make monthly payments. Finally, I take people to court. In the state of Virginia it is easy to take someone to small claims court, if you go out 90 days with no effort to pay, no contact, etc. When I get the judgment, I turn it in to the sheriff to take items to auction. I have gotten many bills paid off because someone did not want to lose their boat. So now my accounts receivable is $30,000 with $20,000 in the 30 days or less category, not bad for a practice that grosses more than a million dollars annually.

8. Final Lesson: “Let it Go!”
You will never make everyone happy in your practice, whether it be an employee, associate veterinarian, or client. No matter whom it is, do not let it weigh you down. Life is too short. In equine referral hospitals and even ambulatory, employees get burned out and may want to leave. I learned that if they have decided to leave, let them go immediately. There is nothing worse than an employee that is unhappy at your practice and recruiting your cli-
ents?. Do the best you can by offering competitive pay, benefits, time off, and ask them what they need. If they still are not happy then it is time to let them go and find someone else because you will never make them happy. Clients also sometimes leave and get second opinions or just get along with another veterinarian better. Just know we give great service, have state-of-the-art equipment and facilities, and have the knowledge base. Not every client is the right client for your practice but may be a great one for someone else’s. You need to know that when you start a practice you get a lot of price shoppers that once they realize you don’t extend credit and aren’t going to just do it for free they will move on to the next new practice. Let them go. You will be happier in the end.

Things to Consider

1. Talk to your employees and see what is making them unhappy and try to make it better but if you have done all you can and nothing changes, let them go.
2. If a client wants a second opinion, do not be offended, let them get one. You would be surprised that a lot of them come back again later.
3. If the client is not happy let them go. Get the clientele that will appreciate your services over the Internet and local experts. But always ask your clients how you can improve your service before you let them go for good.

Bottom line: There is a lot you do not know about practice ownership, because the only way to learn sometimes is making mistakes. Hopefully, learning from others’ mistakes will help you make less in the future. There is nothing more satisfying than owning a successful practice, just make sure you are prepared to take the plunge and enjoy.

Acknowledgments

Declaration of Ethics
The Author has adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Author declares no conflicts of interest.
The Benefits of an Established Social Media Presence Before a Disaster Strikes

Elizabeth Woolsey Herbert, DVM*; and James Meyer, BSc(PV), DVM

Social media can be of great benefit in times of disaster when both volunteers and financing are needed to care for injured horses as well as other animals. You must transition early, and have a significant presence in social media such as Facebook, prior to calling on society for help in these situations. Authors’ address: Adelaide Plains Equine Clinic, 1951 Two Wells Road, Gawler, 5118, Australia; e-mail: ewhdvm@internode.on.net. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction
As social media becomes an ever-more-present force in our lives, veterinary practices are rapidly making the transition from traditional client contacts to Facebook, Twitter, and Instagram for communications. Social media should be seen as a useful tool for practice and can be used for much more than just marketing and education.

In January 2015 a bush fire in our practice area in South Australia burned 49,000 acres over 2 days. Our clinic put out a message on Facebook that we had room for 10 horses. We took in 30 the first night. For comparison, in September 2015 a forest fire near Middletown, California burned 77,000 acres in 2 days. In late November 2015, here again in our practice area in South Australia, a bush fire burned 225,000 acres in 5 hours. People literally ran for their lives leaving stock to fend for themselves. Again, we put out a message on Facebook that we would be happy to take horses that were displaced or injured by the fire.

In the January fire the horses were not burned, and the owners had sufficient time to get the horses out before the fire approached. The horses were stressed, and a few had colic from relocation to unfamiliar locations, lack of water the initial night, and excessive unfamiliar feed presented upon arrival at various facilities. Many regular clients called and wanted to help with the care of the horses housed at our clinic. We initially declined the offer, but we relented when they showed up anyway asking to help with simple things like feeding and cleaning yards. Approximately eight volunteers helped during the January weekend, and then a few were able to continue during the week before we gradually sent the horses home after 7 days.

In the November fire many horses died or were euthanized due to the severity of their burns. Our personal staff lost a total of five horses in the fire. Three of us went out and saw many clients’ and staffs’ horses behind the blockade and euthanized one client’s horse that night. Of the horses we saw on the night of the fire, 12 with severe burns came to our clinic. The burns were primarily legs, ventral abdomen, muzzles, and eyes. Almost all of the horses had corneal ulcers.

Within 48 hours of the disaster, a small army of volunteers had been mobilized, with more than 80
offers of assistance. Some could only come for an hour or two, but in the early phase we would start at 7:00 a.m. and not finish the treatments and cleaning until 2:00 p.m. There would be an hour break and everyone was asked to leave (to prevent them staying and developing fatigue), then a second group of volunteers would come at 3:00 p.m. to start the afternoon medications, cleaning, and feeding.

It also quickly became apparent that financing the care of these extremely intensive patients was well beyond our clinic and the horse owners’ capabilities, and we had to seek other sources of funding. This article aims to share our experiences and advice for utilizing social media during a disaster, and how it can be a useful tool for organizing volunteers, sourcing and promoting funding, and communicating with colleagues.

2. Management of Volunteers
We realized that we could not cope with the needs of the horses with just our staff. Two of our staff had lost homes or horses and were unable to come to work. One of our two veterinarians and a nurse were away treating animals for distant clients. We had eight severely burned horses as well as four with minor burns. Initially on Facebook we called for volunteers to phone with their interest; however, our phone line was quickly swamped, and we edited our request for volunteers to contact us through messages to the practice page.

There were greater than 80 offers of help, which ranged from young horse owners, retirees, veterinary nurses from small animal practices, human burn nurses, veterinary students, and a few colleagues. We grouped them as far as hours available and skill levels. Many of the people who offered their assistance had no prior exposure to horses, and although their offers of help were appreciated, their presence would have been either too time consuming for our staff or potentially dangerous. We usually focused on those with horse-handling experience, and politely declined the rest.

For 3–4 weeks we rotated eight to ten volunteers at a time for a morning session and then another five to six in the afternoon. All the volunteers would accept any task from cleaning stalls to cleaning or holding the sedated horses for daily bandage changes. Key volunteers were identified and were given permission to perform veterinary tasks under supervision, given that only one veterinarian was present at any one time due to scheduled commitments. These rosters were organized using people’s availabilities they provided in Facebook messages to our page.

Volunteers’ skills were maximized by teaming experienced horse people with experienced burns or nursing people, whereas others were grouped into feeders, cleaners, and horse holders. The veterinarians did very little hands-on work after the first few days, given that the volunteers self organized very quickly and rarely did anything they were not qualified to do. They respected each other’s knowledge and experience.

We were concerned about insurance, and we called our business insurance provider and found we needed a policy to cover the volunteers. The policy was not expensive and was put into place immediately to provide cover.

We tried to do daily updates on Facebook to keep up the interest of donators and volunteers. We rarely had pictures of our staff, and tried to make sure all of the volunteers were in a picture at least once. This is not an easy task as several were camera shy. We did group pictures at least once a week and featured them in the postings. As such we implemented a policy that all volunteers agreed to not post specific information (posts or pictures) of individual cases without approval by one of our veterinarians. We did not want owners to get new information on their horses via Facebook. Volunteers were very receptive, and understanding of this, and we had no further issues.

As the horses went home we found that the volunteers were disappointed that their responsibilities were gone and they were not needed. We heard several times that the volunteers were grateful for the experience, and felt they had not done enough. In the end we had a barbeque for all the volunteers and gave them hats with our logo and a volunteer survivor message. Although we still had one horse in the clinic, by sharing our thank you event on social media it acted as a finale for our army of volunteers, donators and supporters.

Key points:

- Volunteer support can be quickly overwhelming in a disaster situation. Encourage potential volunteers to communicate via the Messages section of a Facebook page rather than phoning, to maintain an open line to the practice.
- Acknowledgment of volunteers’ efforts via posts and photos on social media provides instant gratification of their work and also encourages them to engage with the page.
- Adopt a policy during the situation to handle volunteers’ posts regarding individual cases.
- Check with your insurance provider to ensure you have coverage for volunteers. Most policies either include cover or have very-cost effective additional policies.

3. Clinical Advice From Colleagues
Two very experienced volunteers were a burns-specialist nurse who also had horses, and a burns specialist human doctor who was nominated for Australian of the Year for his work in human-burns patients. They heard about our plight through Facebook. The doctor was dealing with the burned human patients from the same fire, but came to visit the horses and give advice. Their help was invalu-
able in treating these horses and suggesting economical ways to clean and bandage legs.

Two equine veterinarians who had dealt with Australian grass fire burns also called and gave advice on the peculiarities, prognosis, and treatment of the burns we saw. There was conflicting advice from the various practices seeing burned horses about treatments such as icing the legs after the initial day, so getting perspectives from other more experienced sources helped us decide which course to take. None of us had dealt with this type of injury on such a massive scale before. Without our engagement in social media, many of these colleagues would not have been aware of our direct involvement in the disaster and we might not have received as much useful advice.

4. Generation and Management of Funding

As treatments began, it quickly became evident that we needed outside ways to finance this as the owners would not be able to pay for the treatments in their current state of losses. Phone calls from colleagues and messages from experienced veterinary emergency response team leaders suggested we start a fund to treat the animals.

There is a vast range of funding sites such as IndieGogo and Crowdrise, but we chose GoFundMe, based on personal recommendations. The first morning after the fire we set up an account that would help in the initial phase of the treatments and supplies needed. There are several funding sites available, but this was simple and would be easy for people who lived out of the country to donate. GoFundMe takes a percentage (∼7–8%), plus 30 cents per donation to manage the fund, and then money is sent directly to a designated bank account almost daily. The GoFundMe site had a list of donors, and we were able to thank each one individually, which we did by email. We put regular updates on the GoFundMe site so the donors who were not regular Facebook followers could see the progress of the horses.

The downside is that this can easily be used for fraud. We monitored other GoFundMe sites that mentioned our name and promised to give the money to us. If we knew them we would ask them not to associate with us and most did comply and stopped their well-meaning sites. We suspect that there were a few that were not going to be so benevolent, so we made it clear on Facebook that our GoFundMe site was the only one through which we were accepting money. Some donators wanted to avoid the percentage lost in the fund transaction and donated directly to our bank account, and we found that this proportion of donors increased over time.

With this scheme we were able to keep up on the financial drain due to the needs of this project. Our first bill for medical supplies, which was only the last 5 days of the month, was $10,000 above what we normally expect. As we were winding down, however, and sending the less-critical horses home, we realized that some of the cost of caring for the horses was not going to present for 6 months or more, such as the water bill. We knew there were other bills like this that would make this a very costly exercise.

Almost 2 months into the project we received a notice that we had been nominated to receive a $10,000 grant from an Australian bank. A distant Facebook follower worked at the bank and was aware of what we were doing through regular updates on Facebook, and she nominated us for the award. We were dubious, but to our surprise, one day $10,000 was placed in our bank account.

Another good source of funds was a group of stallion owners who donated their stallions’ services at half price, and then all the money was directed to our clinic or other practices dealing with burned horses.

We wanted to make sure that we were not included in any rumors of misappropriation of money collected, so we set up a special account in our billing software just for the burned horses, and we applied donations and expenses to that account and anyone could come and see what we did with the money. We did not spend any money for personal food or anything that did not benefit the horses directly. Even our “volunteer thank you” party was from our own sources.

Key points:

- Establishing an online funding account takes a lot of the administrative hassle out of accepting donations. We found GoFundMe to be straightforward and transparent. It also offered convenient solutions for thanking donors.
- Online funding accounts can be easily shared with a clinic Facebook page, and also updated for donors not on social media.
- Monitor pop-up accounts claiming to be donating money to the clinic.
- Donors like options, and direct donations to your clinic bank account is also a valid option. Consider the added time for administering this avenue before offering it.

5. Other Donations

As mentioned previously, some of the first phone calls were from colleagues offering advice about the types of injuries and potential problems we would face in the next few weeks. That was invaluable. One Facebook friend and colleague who had been through this himself, mentioned that he received money and donations of silver sulfadiazine topical cream from colleagues a few years ago, and he wanted to pass on the favor and sent us a large quantity.

As people heard about our plight through social media, we were inundated with products of all kinds.
from bandages impregnated with silver, to honey and aloe vera gels. If we needed something that the general public could get, we would mention it on Facebook and we would be inundated with supplies. We used some products they donated, but as a rule, most with no listed ingredients were not used. In one case we started to use sorbolen for softening the skin and preventing cracking. We mentioned this in an update and then received 180 L of the product. Tack, bandaging items, and especially food were distributed to horse owners, and volunteers. Drug and supplier companies also heard about our needs through Facebook updates and tens of thousands of dollars of products such as silver sulfadiazine topical cream, flunixin, phenylbutazone, bandages, and other products were donated.

When we were certain we had finished with the products, and we heard about other fires and veterinary needs (again, through Facebook), we sent the excess to other clinics. In one case we donated a similar value of money from our first colleague's donation, to the supplier of another veterinary clinic, so they could buy what they needed for their fire-affected horses.

The November fires unfortunately also occurred during a heat wave, and due to the now-very-impaired barrier function of our patients' skin, we had extreme difficulty keeping them cool. There was also a significant safety risk for our staff and volunteers performing treatments for hours a day in 35–40°C (95–104°F) heat. Another company discovered our plight via our Facebook posts and donated three industrial-sized evaporative coolers, free of charge with no expiry period, and delivered and installed them at their own cost.

6. Facebook Utilization

We had what we thought was a good presence on Facebook prior to the November bushfire, with just under 2000 likes on our business page, which we attributed to the regular informative posts on local topics and the sharing of outside horse related posts. The posts on local topics such as poisonous plants, current outbreaks, and items that affect our clients were one of the keys to building this presence. If we wrote a post on a local topic the viewing rate would be in the thousands. If we copied and shared a post from a colleague or magazine the “likes” would be approximatey 100. It is important to take the time to present local informative topics that are shared by the readers. If we asked a client to allow us to share a case in which their horse was the subject, it would be very rare that they would decline.

Early on we asked the owners of the burned horses if they were willing to sacrifice anonymity so we could promote the needs of the horses through social media, and the Internet, and they were more than happy with this arrangement. The first Facebook post on the condition of the horses after the fire had reached 8000 people and was shared more than 1000 times. Within a few days of our initial posts on the horses, our page “likes” went from 2000 to 4000 and has stayed there.

As already discussed, Facebook was a powerful tool for rallying and organizing our volunteers, sharing and generating donations, as well as notifying and communicating with colleagues. Along with calling for volunteers and sharing our funding site, our daily posts with pictures and video were crucial to encouraging viewer sentiment and engaging the public in the trials and tribulations of our patients. Our posts averaged 400–500 words and were accompanied with an average of seven photos. Videos were also infrequently used, and were often short (10–30 seconds) to allow direct upload via Facebook.

Monitoring the staggering numbers of comments on the page was somewhat of an impossibility, but was important as it revealed the differences in how we, as veterinarians vs the public, perceive what we see. We did have a few people with negative comments such as why were we putting these horses through this ordeal. We have found that acknowledging their concerns in a polite and courteous manner was the best way to deal with this. We invited these people to come and visit the horses. Whether we won them over or not is questionable, but at least they did not troll and slam us repeatedly.

Key points:

- A reasonable “like” base for a business Facebook page is necessary prior to utilization in a disaster.
- “Likes” can be generated through sharing of content from other pages; however, information relevant to your geographical location and/or practice focus is most powerful.
- Posts must be kept short for engagement, but contain plentiful information to explain attachments such as pictures and videos.
- While monitoring all comments during a situation such as this is almost impossible, negative comments should be handled promptly and individually. A polite and courteous response, with an offer of engagement is often sufficient. Blatantly abusive comments should be removed.

7. Other Social Media Sites

The practice has successfully utilized other forms of social media, namely YouTube, in the past. YouTube allows for upload of video(s) to the website, which can then be viewed and shared. This is useful as uploading long videos to Facebook can take extended periods of data transfer, whereas sharing a video already uploaded to YouTube is quick and easy. Most videos were kept short during this disaster for direct upload to Facebook, and YouTube was not utilized.

In a quick poll on Facebook we asked whether the people following us used Twitter or Instagram.
We found that only 1 in 5 (20%) people had, or currently, used anything but Facebook. Although this is by any means a biased poll, given that we are only sampling those already using Facebook, we did find that the users of Twitter and Instagram tended to be young. With greater than 1.5 billion users worldwide, compared with 300–400 thousand users individually for Twitter and Instagram,\(^1\) we have always found Facebook to be a superior social media site for our business.

8. Conclusion
Without our initial presence on Facebook none of this would have been possible. You must have a big-enough base to be able to “get the word out” about your needs in a disaster, and hence transitioning to social media early will result in maximal benefit. Although Facebook or social media can be your worst nightmare if not handled well, it can be your friend as well. It allowed us to fund the care of all the animals well beyond the owners’ or our abilities. We did sacrifice privacy, but it was worth it in the end. We had to learn to let go of the day-to-day hands-on control of the treatments, but in the end we have new respect for individuals who just stepped up and did what had to be done in a very difficult situation. Make sure you are insured. Acknowledge the work of the volunteers above any work of your paid staff and yourself.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.

Reference
Composting provides an environmentally responsible and cost-effective alternative for disposal of equine carcasses, compared with methods such as ground burial and cremation. Composting has also proven to be an acceptable alternative to owners as opposed to landfill disposal or rendering. Authors’ addresses: 576 Trapp Road, Auburn, ME 04210 (Melaragno); 2265 Woodoak Drive, Round Lake Beach, IL 60073 (May); e-mail: whistleridge@roadrunner.com. © 2016 AAEP.

1. Introduction

Equine carcass disposal can present dilemmas where local regulations or limited options place restrictions on horse owners seeking suitable methods of respectfully disposing of their companion horse’s body after death. Due to the size of the carcass, owners have limited means of transportation and disposal compared with the relative ease of these processes for small animals. Chemical euthanasia of the horse may further limit the horse owner’s alternatives due to concerns about environmental contamination or unintentional poisoning. Common options available to horse owners may vary with region but may include below-ground burial, cremation, alkaline hydrolysis, rendering, and landfill disposal.

Composting, also referred to as above-ground burial, offers a cost-effective and environmentally responsible option for equine carcass disposal. The method can be performed onsite or at designated facilities. Additional benefits include the ability to utilize waste bedding, which is often readily available on horse properties; low cost compared with cremation; and the production of a usable end product (compost), which provides environmental benefit and allows the composting area to be reused. The composting process produces acceptable degradation of barbiturate and nonsteroidal anti-inflammatory residues, reducing environmental risk.

The purpose of this presentation is to provide the results of 3 years of composting equine mortalities, including the management of composting on a large scale.

2. Materials and Methods

A commercial equine carcass composting business was founded in Auburn, Maine in 2012 in response to increasing interest in environmentally responsible alternatives for disposal. Equine mortalities were collected from properties using handling methods based on Technical Large Animal Emergency Rescue techniques and using equipment such as the Large Animal Rescue Glide and Rescue Straps.
to demonstrate compassion and respect for the human-animal bond. The composting process was based on the content of a certification program offered by the Maine Compost School. The facility operates according to guidelines established in the Compost Management Plan developed by the Maine Department of Agriculture, in accordance with best management practices and Maine Chapter 211 guidelines.

Once transported to the composting facility, the carcasses were composted in windrows using a Pre-condition and Turn method. Where individual composting was requested by the client, the horse was composted in a pile by itself to allow the entire amount of the end product to be returned to the client. Best practices for composting animal mortalities were used, including careful monitoring of windrow internal temperatures.

Horse carcasses were composted in windrows that were pyramid-shaped in cross section to allow for shedding of precipitation; create an internal environment to facilitate the aerobic, thermophilic decomposition process; provide for air inflow into the base of the pile and the formation of a venting “chimney” at the top of the pile (Fig. 1).

Bulking material, the substrate used for the composting process, consisted of used horse bedding (primarily coarse shavings and sawdust, with hay, manure, and urine-soaked bedding mixed in) obtained from local stables. The bulking material was stored in a separate pile and available for immediate use. An approximately 24-in. base of bulking material was placed over a gravel bed surface using a tractor with a front-loading bucket. The carcass was placed in lateral position, with limbs tucked close to ventral body surface when possible, on top of the base (Fig. 2). The carcass was then covered with a minimum of 24 inches of the same bedding material used for the base of the pile. During winter months, an additional 6–12 inches of bulking material coverage was used to insulate the pile and ensure temperatures were maintained.

Once the carcasses were placed in the windrow, internal pile temperatures were recorded daily to ensure that the compost reached a minimum of 131°F (55°C) at a 3-foot depth in the pile for a minimum of 3 days to meet requirements for pathogen destruction (Fig. 3). Once the required minimum was obtained, in-pile and ambient environmental temperatures were recorded one to two times weekly. The piles were not disturbed until 4–5 months after the carcasses were deposited; at that time, a tractor with a front-load bucket was used to “turn” the windrow by fully mixing the contents of the windrow with additional bulking material to start a second heating cycle and to form a second windrow. Bones were mixed back into the new windrow and the windrow was capped with 4–6 inches of bedding to address any potential odor in the newly turned pile. Temperatures were again monitored daily for 7 days and the windrow was turned again at 2–4-week intervals until the active composting phase had ended. Windrows were then screened to eliminate bones, and the piles were placed in a curing phase.

Fig. 1. Diagram of equine carcass compost pile construction. Photo based on Maine Department of Agriculture, Conservation and Forestry, Nutrient Management Program image. Used with permission.

Fig. 2. Horse carcass placed in lateral recumbency on prepared base.

Fig. 3. Measurement of compost pile temperature at 3-foot depth.
The compost was considered mature when the texture was uniform and results of a commercially available test confirmed maturity.\textsuperscript{18} Quality testing of the final compost product was performed approximately 12 months after the carcasses were placed in the windrows.

3. Results

The client charge for composting was comparable to or associated with lower cost than alternative methods (Table 1).

To compost an individual horse carcass of 1000–1200-pound weight, approximately 12–14 cubic yards of bulking material was necessary. Composting the horses in windrows reduced the total amount of bulking material needed per horse by approximately 25–35%.

Each windrow of approximately 14 feet in width and 50 feet in length was able to sufficiently decompose 7–10 average-sized horse carcasses to mature compost in 8–12 months. All windrows and individual compost piles attained temperatures in acceptable ranges within 3–4 days of creation of the pile and maintained acceptable temperatures for longer than the minimum requirement of 3 days (for pathogen destruction).

In properly constructed compost piles (Fig. 1), the pile “yields” on the third day after the carcass is placed in the pile; this occurs when the body cavities of the carcass collapse, and a visible depression is noticed at the top of the pile and some crevices may

\begin{table}[h]
\centering
\begin{tabular}{|l|c|l|}
\hline
Method & Cost, $ & Notes/Availability \\
\hline
Burial & 450–600 & Rental of excavator; operator time \\
Composting & 450–650 & Includes transportation; available year round \\
Cremation & 1700–1900 & Transportation may be additional \\
Landfill & Not available & Not available \\
Alkaline & Not available & Not available \\
hydrolysis & & \\
Rendering & 375 & Limited availability and service \\
\hline
\end{tabular}
\caption{Cost of Disposal of Horse Carcasses in Southwestern Maine}
\end{table}

form (Fig. 4). Piles were reformatted to pyramid shape and additional substrate was placed on the pile at that time to ensure a minimum of 24-in. depth coverage of the carcass.

At the time of the first turning (approximately 4–5 mo), all carcasses had decomposed to bone. Some mane and tail hair remained recognizable (Figs. 5 and 6).

Properly maintained compost piles do not produce offensive odors or drainage, or attract vermin, insects, or predators. On several occasions over the course of a year, shallow digging by a fox was observed but did not extend deeper than 4–5 inches; this was presumably due to the heat present in the pile during the composting process. Minor evidence of worm-harvesting activity by skunks was apparent, but did not extend beyond 3–4 inches in depth. Qualitatively, the number of flies present was similar to or reduced compared with used bedding piles observed on local horse farms.

On average, windrows were turned a total of five to six times (Fig. 7) before the compost product was considered mature via testing. Once mature, the compost was screened to remove large particles and produce a product suitable for consumer use (Fig. 8).

Due primarily to word-of-mouth marketing, the number of horses composted per year increased by
70% from 2013 to 2014 and by 40% from 2014 to 2015. In addition, owners requested composting of other animals, including pets and other livestock kept on hobby farms as pets (Table 2). Initially, many horse owners reacted negatively to the term “composting” but were receptive to the use of the term “above-ground burial” as well as the concept of returning the horse to the earth in familiar material (bedding). Horse owners were comforted by the opportunity to collect some or all of the compost generated from their horse to spread on fields or gardens.

The analysis of the final compost product confirmed that the compost was mature, highly stable and presented no risk of ill effect on plants.

### 4. Discussion

Chemically euthanized horses must be disposed of quickly to prevent poisoning of scavengers, both wild and domestic. Poisonings of wildlife due to mishandled euthanized carcasses may result in federal and criminal charges. In-ground burial is often the first choice of horse owners, likely due to its traditional acceptance for deceased humans. However, burial is not legal in many areas; may not be a viable option for those who do not own the property on which the horse is kept; may not be legal or possible in areas with high water tables; may not be possible due to soil composition or the presence of bedrock or hardpan; and presents concerns regarding soil and ground water contamination. As concerns about the health of our environment grow, increasing numbers of towns/municipalities are placing restrictions on ground burial or prohibiting it altogether. In the anaerobic environment associated with below-ground burial, the carcass does not decompose at a reliable rate due to variation in soil components, weather, and other factors; there are anecdotal reports of nearly intact horse carcasses being discovered 10–15 years after burial. Insufficient burial of a euthanized horse two years prior resulted in the fatal poisoning of two dogs. An additional issue associated with burial for many horse owners is lack of access to appropriate equipment. Excavating equipment is not often readily available and can be costly to rent the equipment and pay a skilled operator.

Cremation is similarly acceptable due to parallels with human methods but may be cost prohibitive, may not be available in some areas due to the limited number of facilities, and is associated with the production of greenhouse gases and potential pollutants. In addition, some facilities that accept horses for cremation do not have equipment sized properly to accept intact horse carcasses, and must section the carcasses to cremate them; this is not acceptable to many horse owners.

Alkaline hydrolysis, also called water cremation or green cremation, utilizes water and sodium hydroxide or potassium hydroxide to reduce the carcass to liquid and bone. When used for animal carcass disposal, the liquid (composed of amino acids, peptides, sugars and soap) can be distributed on fields. The process successfully degrades chemicals (including pharmaceuticals) and kills pathogens. The process is more environmentally responsible compared with flame cremation. Disposal of an average-sized horse carcass using commercially available alkaline hydrolysis can be performed in 18–20 hours. At this time, alkaline hydrolysis is not widely available. Commercially available units capable of accepting an intact horse carcass cost several hundred thousand dollars, making them cost prohibitive for many areas.

Rendering has steadily become less available in many areas due to reductions in the number of companies providing the service. Rendering is an un-

<table>
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<th>Year</th>
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<th>Alpacas/Llamas</th>
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desirable option for many horse owners due to anecdotes regarding mishandling of their horses’ bodies; the idea of their beloved animal being dismembered and processed into numerous products; and long-standing rumors regarding the use of rendered animal tissues. In addition, chemically euthanized animals are undesirable to renderers due to barbiturate residues that survive the rendering process.9–11 Horse owners and equine practitioners have experienced poor and inhumane handling of horse carcasses by some renderers, including decapitation of some animals and audible long bone fractures as the horses’ bodies are pulled onto a truck using a winch cable tied around their limbs or throatlatch. One veterinarian was aware of a rendering company hired to haul a horse home from a referral center in which the truck operators attempted to extort additional payment from the horse’s owners with a threat to dump their horse’s carcass on the side of the road.12

Not all municipal landfills allow disposal of large animal carcasses, and landfill disposal is aesthetically displeasing to many horse owners who feel their beloved companion is being “tossed out with the trash.” Landfills also present environmental challenges as the available space for landfills steadily reduces.12

Composting provides a means of disposing horse carcasses that is overall superior to alternatives because it is environmentally responsible, cost effective, and produces a useful and beneficial end product. Unlike burial, properly maintained compost piles do not present the risk of groundwater contamination, and the composting surface can be reused numerous times. Unlike cremation, composting does not require specialized equipment and does not produce greenhouse gases. Composting is preferable to rendering because composting results in adequate destruction of pharmaceuticals such as barbiturates. Alkaline hydrolysis is comparable to composting with regard to environmental effect, but requires specialized equipment and is not widely available.

Composting can be performed onsite (in accordance with state regulations, including minimal setback distances and permit approval where necessary) or at designated facilities. Additional benefits include the ability to utilize waste bedding, which is often readily available on horse properties; low cost compared with cremation; and the production of a reusable end product (compost), which provides environmental benefit and allows the composting area to be reused. The composting process produces acceptable degradation of barbiturate and nonsteroidal anti-inflammatory residues, reducing environmental risk.14–21

Composting, particularly when communicated as above-ground burial, is acceptable to horse owners who demand that their animals be handled in a respectful manner, even after death. Combining composting, or any means of disposal, with compassionate and respectful handling increases its acceptability to horse owners.

An intact horse carcass can be reduced to usable, mature compost in approximately 8–12 months with proper management. Although careful monitoring is important, if done as a commercial endeavor it does not require significant amounts of time and the composting business can be maintained as supplemental to other employment.

Analysis of mature compost at 12 months after initial carcass placement confirmed that the composting process yielded high-quality compost suitable for use on fields and gardens.

However, composting should only be undertaken by those with a solid understanding of the process involved and the proper maintenance of compost piles to ensure adequate decomposition and production of a mature, useful end product. Certification is recommended to ensure that best practices are understood and followed. The compost pad must be properly located and constructed to facilitate appropriate composting. Depending on local and/or state regulations, a designated composting facility should operate according to guidelines established in a facility-specific compost management plan approved by state agricultural authorities, conservation authorities, cooperative extension, or other relevant authorities.

State regulations vary, and many states require permits to compost animal carcasses, especially those that did not originate from the land on which the composting is being performed. Prior to composting large animal carcasses, consult your state regulations or natural resource council.

Many horse owners become deeply bonded to their horses, and expect that their animals will be handled in a respectful and compassionate manner even in death. Composting, or above-ground burial, provides an environmentally responsible alternative for disposal of equine carcasses; combining composting with appropriate techniques for moving large animals provides an environmentally responsible disposal option that respects the human-animal bond.

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Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors declare no conflicts of interest.
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Economic Analysis of Acupuncture Profitability as Applied in Current Equine Private Practice

KT Steward, DVM*; and Martha Mallicote, DVM, DACVIM

Acupuncture is a quickly rising field of interest in equine medicine. With an increased demand from clients and an increased number of practitioners becoming acupuncture certified, it becomes important to examine the application and profitability of acupuncture in current private practice. This paper will examine the cost and benefit of practicing acupuncture both as a therapy and as an adjunctive diagnostic tool, as well as to explore how private practices are charging for their services. Authors’ addresses: Peterson and Smith Equine Hospital, 4747 SW 60th Avenue, Ocala, FL 34474 (Steward); and 10626 SW 12th Terrace, Micanopy, FL 32667 (Mallicote); e-mail: ktstew@me.com. *Corresponding and presenting author. © 2016 AAEP.

1. Introduction

Acupuncture is a quickly expanding service offered in the field of equine medicine. In principle, acupuncture is the insertion of needles at specific points on the body with the intended purpose of changing the body’s physiology. The mechanism by which this occurs is unclear but theories include a decrease in inflammation, an increase in circulation, or stimulus of opioid receptors resulting in alteration of neuropathways.1,2 The efficacy of acupuncture has been documented anecdotally and an increasing number of studies in recent years have successfully focused on providing quantitative data to support its use both as a therapy and as a diagnostic tool.3 As the Western scientific community continues to explore the benefits of Eastern medicine, horse owners are also seeking these therapies for their animals. According to the 2013 American Association of Equine Practitioners (AAEP) Touch report, 38% of owners named having a practitioner that is knowledgeable about the latest developments and treatments in equine medicine,” only 35% agree strongly that their veterinarian can be described that way. That 17-percentage-point difference is the largest gap between importance and performance among the 20 attributes measured. Further, 10% of horse owners surveyed had used the services of a veterinarian other than their primary veterinarian to perform acupuncture, compared with 4% that used their primary veterinarian for acupuncture.4

As clients express interest and willingness to explore alternative therapies, more and more equine practitioners are becoming trained and certified to perform acupuncture, chiropractic manipulation and other complementary therapies each year. Currently, acupuncture is not part of the veterinary school curriculum but instead must be acquired as continuing education, either as a student during holidays and breaks from school or following the completion of veterinary school. As such, becoming certified in acupuncture is not without cost as practitioners must take the time to travel, study, and
pay tuition for certification. The objective of this research was to examine the cost and benefit of practicing acupuncture both as a therapy and as an adjunctive diagnostic tool, as well as to explore how private practices are charging for their services.

**Solution**

Certification in veterinary acupuncture is a costly investment. Practitioners desiring to widen their knowledge base in this matter need to be prepared to charge clients for the application of newly developed skill sets. Because clients strongly value veterinarians who are up to date on the latest techniques and developments, charging for additional skill sets should be readily accepted. Through appropriate client communication and marketing of acupuncture services, returning the investment of certification should not be a difficult task and will also expand the depth and quality of patient care in private practice.

2. **Materials and Methods**

This study was conducted using Qualtrics survey program licensed through the University of Florida. A survey consisting of an informed consent form and twelve questions was distributed to veterinarians. The survey collected descriptive data about the veterinary practice, information about the practice’s use of acupuncture therapy and pricing of these services. The final question was only displayed to the contributor should their previous questions match defined criteria. There was no compensation given to contributors. All contributed content was anonymous and all questions were optional.

The survey was distributed through the AAEP General Discussion forum (1388 links sent), the AAEP Business Education Rounds forum (506 links sent), and the AAEP Complementary & Alternative Meds Round forum (282 links sent). Additional distribution to members of a private alternative therapy listserv was provided by an acupuncture-certified veterinarian (total distribution unknown).

3. **Results**

**Sample Population**

Sample population questions were posed to respondents regarding practice size, client disciplines, and geographical area of practice (Fig. 1, A–C).

**Application of Acupuncture**

Of the 109 respondents, 63 reported to offer acupuncture performed by a certified acupuncturist in their practice. Of those practices, 61.84% of practitioners were acupuncture certified. Of practices using acupuncture, reported use averaged 38.4% therapeutic acupuncture treatments and 43.45% indirect use of acupuncture in diagnostic evaluations. Among these respondents, 32% reported that therapeutic acupuncture treatments made up less than 10% of their total acupuncture use.

**Therapeutic Acupuncture**

Multiple and various modalities of treatments for acupuncture therapy were reported by respondents (Fig. 2). Dry needling was the most common modality (36.9%). The most commonly reported therapy listed in the Other category was laser acupuncture.

The most commonly reported time period for a practitioner to spend with a patient on acupuncture therapy treatments was 45 minutes (44% of respon-
Thirty-one percent of respondents reported spending 30 minutes on therapy, 17% spent greater than 1 hour, and 8% spent 15 minutes or less. The average time for a practitioner to spend with a patient while administering acupuncture treatment was 42 minutes.

Seventy-six percent of practitioners who used acupuncture therapy in their practice reported charging a flat rate for treatments and five of the 44 respondents (11%) in this category reported to have a variable or decreased flat rate depending on the established or new status of the client. Six percent of practitioners charged an hourly rate and the remaining 18% reported variable rates based on the type of therapy, materials, and time spent. The most commonly reported flat rate was $100, followed by $150. In the cases that respondents reported a range of flat rate pricing, the average of the range was included in the figure. The weighted average flat-rate charge for acupuncture was found to be $126.17 (Fig. 3).

The average overhead cost to the practitioner was reported for each type of acupuncture therapy (Fig. 4). The largest overhead cost was associated with aqua-acupuncture, but overhead for all therapies were less than $20 per treatment. The average overhead cost was $17.33.

Diagnostic Acupuncture

On average, respondents reported their routine lame
ness examination consisted of 23% diagnostic acupuncture. The highest number of respondents reported that diagnostic acupuncture made up 1–10% of their lameness examination (Fig. 5).

Forty-one of 59 respondents (69%) reported that they charge the same amount for lameness examinations including acupuncture compared with lameness exams that do not include acupuncture. Two of 59 respondents (3%) reported a higher charge for lameness examinations that include acupuncture diagnostics. These two respondents reported charging $20 and $50 more when acupuncture is included than their fee for a lameness examination that does not include such diagnostics.

Of the respondents who reported charging the same amount for lameness examinations with and without acupuncture, 26% indicated that they felt the time spent using acupuncture for diagnosis did not validate an upcharge. The remaining 74% indicated that either their client expected acupuncture to be included in diagnosis or that acupuncture...
diagnostics were included within the routine lameness examination fee.

4. Discussion

For the data set collected, the average profit margin for acupuncture treatments as a therapy, as calculated from the average overhead ($17.33) and average flat rate ($126.17) is $108.84 per session. Analyzing the gross profit potential with regard to the average time spent with each patient (42 min), the average net income of practitioners administering acupuncture treatments as therapy is $2.59 per minute ($108.84/42 min), or $155.49/hour. According to the 2015 American Veterinary Medical Association Report on Veterinary Compensation, the median professional gross income of equine veterinarians is $87,000 and the median number of work hours per week is 58.\(^5\) This means that equine veterinarians working 50 weeks of the year tally 2900 hours and earn a median gross income per hour of $30.00, nearly a fifth of the gross income per hour for acupuncture therapy. This high level of profit results from the relatively low overhead cost of acupuncture therapy (reportedly less than $20/treatment). However, it is not certain whether respondents included a portion of the fixed costs of running their business in this figure, or whether it was strictly based on the specific costs associated with the acupuncture services provided.

It is then important to evaluate whether the cost of acupuncture certification will be profitable based on the intended use of acupuncture in practice. Using the Chi Institute in Florida as an example, the current cost of tuition for acupuncture certification ranges from $800-$1700 per 4-day class session.\(^6\) Three class sessions, two online sessions, and a $350 final examination are included in the curriculum. The listed total price for tuition for the International Veterinary Acupuncture Society (IVAS) basic veterinary acupuncture course is $6495, comparable to the Chi Institute.\(^7\) At a net income of $108.84 per acupuncture session, 60 acupuncture sessions are required to pay for tuition alone. This tuition does not include travel, lodging, and time away from the practice. Acupuncture certification is not a negligible expense; however, it is one that could be justified and depreciated over time depending on the amount of acupuncture therapy intended to be performed.

In the population studied, only 38.4% of overall acupuncture practice is spent using acupuncture treatment as a therapy. Indirect use of acupuncture as a diagnostic tool was reported to be more common (43.45%) but was less commonly billed to the client. In the majority of responses, the fee for indirect acupuncture use was reported to be “part of” the examination/diagnostics fee. It is not clear whether this bundling of fees is made known to the client, or whether the client is aware of the additional use of acupuncture diagnostics during the course of the lameness examination. This is a relevant point of interest given that 32% of respondents reported that acupuncture therapy makes up less than 10% of their acupuncture practice. Because of the apparent lack of billing for indirect use of acupuncture, it is unclear whether acupuncture certification would be overall profitable in this represented average of respondents.

The limitations of this study were inherent in the style of data collection used. To generate responses, the survey was kept short and none of the questions were required, allowing respondents to skip questions should they choose. As such, some of the responses were not able to be interpreted because they contained partial or incomplete answers. Respondents were asked to answer questions based on estimated percentages in their practice and therefore exact quantitative totals for income and caseload were not gathered. It is also worth noting that the data averages used do not account for diverse demographic regions within North America and may not be applicable to regions that are far above or below the mean.

A follow-up study examining client interest in acupuncture diagnostics specifically as well as their awareness of its current use by their veterinarian could add value to this study by revealing client willingness to pay fees for additional or augmented diagnostics. In addition, evaluation of the potential for acupuncture certification to increase client satisfaction and ultimately increase client base without increasing the charges for services rendered may also prove worthwhile.

Acknowledgments

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Declaration of Ethics

The Authors have adhered to the Principles of the Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors declare no conflicts of interest.

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