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.

Future AAEP CE Dates

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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 San Francisco 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 and 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 name(s) of the paper author(s). Content is scored using the criteria of Study Design, Study Quality, Innovation and Impact, Practicality, and Manuscript Quality. This year 196 papers were submitted for the 50 available slots on the program.

Non-scientific sessions addressing business, 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 is rigorous. It requires an enormous effort by every one of the 50 EPC members to create the best possible program for the AAEP membership. Many volunteer hours were spent putting together the San Francisco program, so please thank them for all their hard work creating this program for you.
Dear AAEP Members & Guests:

Welcome to the 64th AAEP Annual Convention in fabulous San Francisco. It has been 27 years since we have visited San Francisco, a city known for the Golden Gate Bridge, rolling city streets navigated by iconic street cars, internationally acclaimed art and architecture, Chinatown, Fisherman’s Wharf and Alcatraz... not to mention splendid restaurants!

I have no doubt that the myriad attractions of this city will perfectly complement the excellent educational program planned. Dr. Jeff Berk, the 2018 Program Chair and President-elect, has worked tirelessly to provide a perfect mix of practical material and evidence-based medicine. There will certainly be something to “take home” for everyone. Great thanks are owed to the heart of the AAEP educational mission—the members of the Educational Programs Committee. The “EPC” members represent all aspects of equine practice and expertise, thus representing you, the AAEP. Through the leadership of Drs. Phoebe Smith (Chair), Charlie Scoggin (Vice Chair) and Ed Kanara (CE Consultant) this group takes pride in providing relevant, state-of-the-art content that can be integrated into a multitude of practice settings. The only limitation to the program is having the time to see and hear it all!

Of course, a spectacular meeting such as the AAEP Annual Convention is made possible by the efforts of many. The AAEP staff work behind-the-scenes to ensure that every detail of our educational offerings meets the standards and needs of our members. Our Educational Partners contribute to the framework of our excellent CE offerings in many ways: offering quality products, partnering with practitioners to help horses, and financially supporting AAEP educational efforts. The wonderful meeting experience that we have grown to expect with the AAEP truly would not be possible without the support of our Partners. Be sure to plan time in our extensive Trade Show where I hope you find the opportunity to thank our Partners and exhibitors for their support.

Reflecting on the year in review, there has not been a quiet day in the AAEP’s efforts to help horses and equine veterinarians. Many of you, our volunteer members, have generously given your time and intellect on topics ranging from student debt to bisphosphonate use. Through the efforts of several work groups, we have made strides in improving equine welfare by addressing misuse of medications and training methods for horses, the overpopulation of wild horses and burros on public lands, and a continued emphasis on scope of practice. Others are looking, hard, at what drives an equine veterinarian out of bed every day and fuels the passion to stay in the profession for the long term. We hope that mentoring of equine veterinarians, both young and old, will prompt more vets to establish equilibrium between work, play and family in their lives. Still others have focused on factors that affect us, the veterinarians that care for the horses that we love. In 2018, our Wellness subcommittee spearheaded a campaign to improve heart health in equine veterinarians. Implementation of healthier diets and exercise habits, reducing stress and ensuring practices are equipped with AED’s are a few areas that have been highlighted for our members.

We have no shortage of skilled, eager volunteers within our membership. While our organization can seem large at times, the member voice is always the strongest voice. Whether you participate in a table topic, write a response on a Rounds listserv or contribute to a member survey, please know that we value your input.

Enjoy your time in San Francisco as you learn new things and meet new friends. Thank you for your honest thoughtful opinions, strong support and warm wishes over the past year.

Margo L. Macpherson, DVM, MS, DACT
2018 AAEP President

Raising the Standard in Horse Health
As program chair for 2018, I welcome you to San Francisco for the 64th AAEP Annual Convention. The Educational Programs Committee, under the direction of Dr. Phoebe Smith, Dr. Charlie Scoggins and Mrs. Carey Ross, has created a comprehensive and practical program.

Here are some of the highlights:

- **Keynote Speaker**: Abraham Verghese, MD is a bestselling author and National Humanities Medal recipient. He will discuss how modern medicine is in danger of losing its most powerful tool: the human touch.
- **Kester News Hour**: Drs. Rob MacKay, Regina Turner and Wes Sutter will present “what’s new” in a concise take-home format in the areas of medicine, reproduction and surgery.
- **Milne Lecture**: Dr. Virginia Reef will present “Straight from the Heart: Untangling the Complexities of the Equine Cardiovascular System”.
- **In-Depth Sessions**: Ultrasonography in Lameness Diagnosis, Endocrinology in Geriatrics, Pre-Purchase Exam for Sport and Pleasure Horse, Complementary Medicine, Touch: Core Communication Skills for Highly Effective Practitioners. Some of these sessions will be interactive so that the attendees can respond to the presenter’s questions using their smartphone or other devices.
- **How-to Sessions**: Dentistry, Diagnosing Poor Performance in the Equine Athlete, Field Anesthesia and Pain Management.
- **Interactive Ethics panel discussion with experienced practitioners**.
- **Wild Horses on BLM land**: problems and potential solutions . . . expert guest speakers including Ben Masters, creator of the movie “Unbranded”.
- **Lifestyle and Wellness**: Recognizing and Managing Addiction in Practice.
- **Table Topics on everything equine**.
- **Abstract sessions focused on lameness, medicine and surgery**.
- **Back to Basics**: Lameness/Podiatry.
- **Business Sessions**.
- **Experiential Learning**: Dry Labs Using Models.
- **Trade Show**: visit the more than 300 exhibitors, many of whom are AAEP Educational Partners. Be sure to thank them for helping make the Convention the world’s best equine CE meeting.
- **Events**: Receptions, President’s Luncheon, The After Party, Vet Story Night, Health Fair and Exercise Classes.
- **Student Events**.

As if that’s not enough, there’s also San Francisco to explore. Hope you enjoy the meeting!

Sincerely,

Jeffrey T. Berk, VMD, MRCVS
2018 AAEP President-Elect

Raising the Standard in Horse Health
2018 AAEP Board of Directors

President
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2020
Duane E. Chappell, DVM
Foster Northrop, DVM
Deborah L. Spike-Pierce, DVM, MBA

2018 AAEP Awards

Distinguished Educator Award (Academia) – Dr. John A. Stick
Awarded to an individual educator, who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners.

Distinguished Educator Award (Mentor) – Dr. Richard “Chip” Estes
Awarded to an individual who by his or her actions and commitment has demonstrated a significant impact on the development and training of equine practitioners through mentoring.

Distinguished Service Award – Dr. W. Kent Fowler
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.

Sage Kester Beyond the Call Award – Dr. Thomas R. Lenz
This award is named in honor of its first recipient, the late General Wayne O. “Sage” Kester, DVM, and represents the highest honor bestowed by the AAEP upon a current or former member. The award is presented to an individual who has made significant and long-lasting contributions to equine veterinary medicine and the community. This individual not only possesses the qualities of a leader with a strong commitment to the health and welfare of the horse, but also impacts and improves the lives of others through service above self.

AAEP Research Award – Dr. C. Wayne McIlwraith
The AAEP Research Award recognizes an individual who has recently completed research that has or will make a significant impact on the diagnosis, treatment or prevention of equine disease.
General Instructions for Authors
65th AAEP Convention
Denver, Colorado
December 7–11, 2019

To submit a paper, go to https://aaep2019.abstractcentral.com

ALL papers must be submitted online by March 15, 2019, 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 at the end of this document) 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 can be found in their respective sections.

Format:
- 12 point, Times New Roman font
- Double-spaced
- 1" margins

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 concise summary 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 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.

Recommended Nomenclature:
Anatomy and anatomic planes should be described using standard nomenclature following the guidelines developed by Nomina Anatomica Veterinaria [http://www.wava-avma.org/downloads/nav_2012.pdf]

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 Acknowledgments 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 Practitioners’ (AAEP) policy requires that authors must disclose and describe the nature of any actual or potential financial and/or personal relationships 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.) 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 HCLa (10-20 mg/kg IV) and butorphanol tartrateb (0.01-0.02 mg/kg IV).
a Dormosedan® Orion Corporation, Espoo, Finland.
b Torbugesic®, Fort Dodge Animal Health, Fort Dodge, IA 50501.

Figures:
The resolution should be at least 300 dpi. Figures should be cited in the text in parentheses (Fig. 1) consecutively in the order of which they are first mentioned. The figure itself should also be numbered to correspond to the citation in the text. Figures must include captions, 40 words or fewer.

Figures, tables, and text should all be included in the same document.

Tables:
Table should be self-explanatory and should supplement the text. Provide a concise, descriptive title for each table. Figures, tables, and text should all be included in the same document.

Permissions:
If you wish to use previously published material, including text, photographs, or drawings, you must acknowledge the original source and submit written permission from the copyright holders (author and publisher) to reproduce the material. Provide this permission when you submit your original manuscript.

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 (USDA).

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 online by March 15, 2019, 3:00 p.m. E.T.; 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 websites, 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://aaep2019.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 who have agreed to volunteer their time to mentor an author who needs guidance. To see this list, email Carey Ross at cross@aaep.org.

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Scientific Papers: Guidelines for Authors
65th AAEP Convention Denver, Colorado December 7–11, 2019

To submit a paper, go to https://aaep2019.abstractcentral.com

ALL papers must be submitted online by March 15, 2019, 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, with no upper word limit.

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The “How to” Paper: Guidelines for Authors
65th AAEP Convention Denver, Colorado December 7–11, 2019

To submit a paper, go to https://aaep2019.abstractcentral.com

ALL papers must be submitted online by March 15, 2019, 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 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, with 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 if 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 in the take home message. Case selection, case study number, and case follow-up should all be included.

In the Discussion, 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 in the take home message. Case selection, case study number, and case follow-up should all be included.

Abstracts ≤ 250 Words: Guidelines for Authors

For those who intend to publish in a refereed journal
65th AAEP Convention
Denver, Colorado
December 7-11, 2019

To submit a paper, go to https://aaep2019.abstractcentral.com

ALL papers must be submitted online by March 15, 2019, 3:00 p.m. ET.

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 and 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 author’s 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
65th AAEP Convention
Denver, Colorado
December 7–11, 2019

To submit a paper, go to https://aaep2019.abstractcentral.com

ALL papers must be submitted online by March 15, 2019, 3:00 p.m. ET.

The general theme for the 2019 Business of Practice Sessions is “Growing Your Practice in Current Economics Times.” 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. Papers are allotted a total speaking time of 20 minutes (15 minutes presentation time + 5 minutes questions). The following topic suggestions are intended to spark ideas that relate to the “Growing Your Practice in Current Economic Times” theme. We also welcome paper submissions on any topic pertaining to the Business of Practice.

Potential Topics:
• Marketing strategies, leveraging your time and investment
• Areas for growth
• New services for your practice, how to introduce them and make them successful
• Social media strategies
• Staff interactions with clients around marketing and new services
• Building better client relationships
• Marketing strategies for the practice
• Resources and investment of time
• Understanding your practice, the area, and the opportunities

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Heads may include (but are not limited to) the following:
1. Take Home Message (not required for “How to” papers. See section at the end of this document for “How to” paper guidelines).
2. Introduction
3. Solution
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:
Breaking the Silence: Disclosing Medical Errors

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This should be a concise summary 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.

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Solution:
A description of a single or multiple business solutions are explained in detail.

Results:
Any results should be presented in this section. If the data can be well represented with a table or figures, these are encouraged.

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Practical Use of Ultrasound in Thoroughbred Racehorse Lameness Diagnosis

Chris O’Sullivan, BVSc, MS, DACVS

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1. Introduction

Ultrasound is one of the key diagnostic tools used in Thoroughbred racehorse lameness diagnosis. When first introduced into practice, the ultrasound’s primary role was the investigation of tendon and ligament overstrain injuries, and this has remained its mainstay application in racetrack practice. However, as a modality, ultrasound’s role has diversified and is now commonly used for investigation of a variety of other sites of lameness, including joint, muscle, and bone injuries.

2. Primary Role of Ultrasound

Tendon Injuries

When investigating tendon overstrain injuries, ultrasound is still the primary diagnostic imaging tool used. In racing Thoroughbreds, the most commonly identified tendon injury is an overstrain injury of the superficial digital flexor tendon (SDFT), while injuries of the deep digital flexor tendon (DDFT) are relatively rare. The following discussion will focus on the more commonly injured SDFT. Tendon injuries are less common in 2-year-olds than older horses, and the reported incidence of flexor tendon injuries in Thoroughbred racehorses in training varies in different racing populations, with the incidence ranging from 8% to 43%. In the author’s practical experience over the last 20 years, the incidence at Randwick Racecourse of tendon injuries has significantly reduced. The reasons for this are likely multifactorial, with changes in training, veterinary supervision, and shoeing occurring during this time. Although the track surfaces have not changed, horse and vehicle crossings have been removed and trainers appear to be more astute observers of poor track conditions and avoid work on it in that state. Combined, these factors have likely contributed to the reduction in tendon injuries seen by the author’s practice.

Typical presentation of an injured SDFT in a Thoroughbred racehorse includes swelling, heat, and pain in the region of the flexor tendons. Assessment of detailed work history associated with the swelling assists in determining the likelihood of the injury being an overstrain-induced tenosynovitis with damage to the tendons structure described as a “bowed tendon.” Alternately, the swelling could be only a minor peritendinous swelling “bandage bow” without any damage to the tendon structure.

Once an accurate history is obtained, a thorough clinical examination is conducted, commencing with observation of the flexor tendons’ profile combined with manual assessment. Palpation of the tendon between thumb and forefinger with the limb, both
weightbearing and non-weightbearing, allows any subtle thickening to be identified. When holding the limb up, work along the margins between the SDFT and DDFT while applying moderate firm pressure to the SDFT. When this palpation elicits an obvious sharp pain response, it is highly likely that there is an active tendonitis present. During weightbearing, ensure that the branches of the SDFT in the pastern and the proximal tendon/musculotendinous junction at the level of the carpus are carefully assessed for enlargement. The digital and carpal sheaths should be assessed for effusion. The lameness associated with SDFT tendon injuries is typically fairly mild, approximately 1 to 2 grades out of 5 at the trot on firm ground and may be absent or only transient and does not always correlate with the severity of the injury. Lameness typically improves rapidly over the first couple of days. However, in rare cases, a significant severe lameness may accompany a moderate tendonitis. Severe lesions typically have marked generalized soft tissue swelling around the flexor tendons, making accurate palpation of the tendons borders difficult, and the most severe cases may result in loss of fetlock joint support, with an obvious dropping of the fetlock when weightbearing.

Clinically apparent swelling, heat, and pain on palpation over flexor tendons indicate the need to consider an ultrasonographic evaluation to rule out a tendonitis. Given the propensity for tendon overstrain injuries to become more obvious over the first 1–3 weeks, delaying a scan for 1–3 days initially while weightbearing and non-weightbearing, allows any subtle injuries or those scanned closer to the time of injury and these include use of an off-incidence probe angle, doppler imaging, plus scanning the limb both weightbearing and non-weightbearing. These techniques combined with the more traditional serial monitoring of measurements are useful for the ongoing monitoring of rehabilitation.

In the author’s experience, the most common cause of SDFT injuries in racing Thoroughbreds is likely an accumulated overstrain injury, and these typically have a poorer prognosis than the less common injury caused by a single incidence or bout of overstrain, such as a horse getting loose and bolting or overreaching and causing peripheral injury to a loaded tendon. The accumulated tendon overstrain cases will more likely have a discrete core rather than peripheral injury, and there is often accompanying subtle, generalized ultrasound changes in the contralateral uninjured tendon, suggestive of accumulated subclinical damage in both tendons.

Intratendinous therapies, such as stem cells and platelet-rich plasma, can be delivered via ultrasound-guided needle placement into a core lesion. Ultrasound monitoring of healing has been well documented; in the author’s experience, the only downside is trying to balance any misguided client expectations that a pleasing ultrasonographic appearance of healing represents a completed healing process and reason to accelerate rehabilitation. It seems far more accurate to determine the rehabilitation plan at the initial injury phase by using a specific time duration and then use ultrasound to ensure the tendon is coping with the load being applied during the rehabilitation plan. Most significant overstrain core injuries require at least 9–12 months prior to being healed sufficiently to cope with a full training workload. The assessment of healing or overall tendon health may be guided in the future with developing ultrasound techniques, such as sonoelastography or ultrasound tissue characterization techniques.

Suspensory Ligament Injuries

Similar to flexor tendons injuries, those affecting the forelimb suspensory ligament body and branches generally have similar associated clinical signs with heat, swelling, pain on palpation, and variable lameness. Any evidence of a sudden increase in the size or shape of the suspensory ligament is an indication to investigate ultrasonographically. Ultrasound of the suspensory ligament can be divided into three major regions: the branches, body, and proximal region. Proximal sonography is complicated by the position of the suspensory ligament deep within the confines of the splint bones and the variable echoge-
nicity of the ligament in this region due to the vari-
ability presence of hypoechoic muscle tissue and the
biloched shape of the ligament at its insertion on the
proximal metacarpus. The distal branches are
more easily scanned, and pathology will often run
down to the sesamoid attachment. Cases with in-
juries close to or involving the insertion onto sesa-
mooids benefit from a radiographic series of the
fellock to assess the level of sesamoiditis and rule
out the presence of a sesamoid fracture. Alter-
nately, injuries of the proximal suspensory insertion
on the cannon bone also benefit from radiographic
evaluation to rule out avulsion fracture or bone
injury.

The proximal suspensory ligament region and its
insertion on the palmar region of the metacarpus is
one of the more common sites of lameness in the
author’s Thoroughbred racetrack practice where
horses are trained on a variety of tracks, including
sand, dirt, poly, and turf. The majority of these
cases appear to be a transient inflammation of the
periligamentous tissues without any obvious struc-
tural damage to the suspensory ligament itself.
This inflammation, within the anatomical confines
of the proximal suspensory region, causes the cli-

cial signs typical of proximal suspensory lameness,
including a transient mild to moderate lameness
(grade 1–2/5), with very subtle swelling and heat in
the proximal suspensory region (proximal third of
the palmar metacarpus when assessed in a standing
position). Firm palpation when non-weightbearing
with the carpus flexed generally elicits a sharp pain
response, but there is no obvious palpable thick-
ing of the suspensory ligament itself when compared
with the contralateral unaffected limb and using the
caudal border of the splint bones as a reference.
Both fetlock and carpal flexion tests will often elicit
a worsening of the lameness, as will firm palpation
of the proximal suspensory ligament, but responses
can be variable with all three manipulations. The
horses can also show increased lameness on the turn
at the walk or when decelerating in transition from
trot to walk. The surface they are trotted on can
also influence the lameness as can the presence of
a rider. Ultimately, local anesthesia may be re-
quired to determine the proximal suspensory re-
gion as the site of lameness. Ultrasonography is
generally unnecessary in these cases, as the ma-

jority respond quickly to phenylbutazone, ice, rest,
and reduced workload with for 3–5 days, with res-
olution of lameness, swelling, and pain. Alter-
nately, cases can be treated with a regional infil-
tration of corticosteroids as well. Ultrason is
indicated for cases that fail to respond to the above
treatment approach.

Injuries suspected as having a desmitis or an
insertional bone injury of the proximal suspensory
ligament are indicators for immediate imaging,
starting with ultrasound (linear 7.5–14 Mz) of the
proximal suspensory region. The exam should be
performed both weightbearing and non-weight-
bearing, including using an off-incidence tech-
nique, as mild injuries will be missed if relying on
weightbearing sonography alone. In addition, ra-
diographs of the proximal cannon bone can assist
in ruling out obvious insertional bone injury but
has a low sensitivity for bone lesion in this area.
These cases with either a true desmitis or inser-
tional bone injury tend to respond poorly to anti-
flammatory therapy with persistent swelling and
variable lameness. On presentation, they
tend to be more lame (grade 3–4/5) and have a
more focal pain response on palpation compared
with cases with only periligamentous inflamma-
tion. The suspensory ligament will palpate obvi-
ously thickened when assessed with the carpus
flexed in a non-weightbearing position, often with
swelling more palmar than the palmar border of
the splint bones. Similar management and reha-
bilitation to flexor tendon overstrains can be used,
with large suspensory body core lesions requiring
a similar 9–12 months. Suspensory branch inju-
ries and proximal suspensory insertional injuries
can often be rehabilitated more rapidly, with year-
lings and 2-year-old horses often able to be reha-
bilitated based on ultrasonographic healing with
some suitable to return to training as early as 3–4
months.

Digital Sheath Soft Tissue Injuries
Soft tissue injuries involving the digital flexor ten-
don sheath (DFTS) typically cause lameness, swell-
ing, and enlargement of the structure damaged
within the tendon sheath, along with varying de-

grees of DFTS effusion in the acute phase. The
most common injuries in Thoroughbred racehorses
in this region are overstrain injuries of the SDFT or
sesamoidean ligaments. Overstrain of the oblique
sesamoidean ligament is clinically indistinguishable
from injuries of the SDFT distal branches and
causes a typical swelling in a small anatomical tri-
gle created by the border of the sesamoid bone
proximally, margin of P1 dorsally, and the diverging
edge of the SDFT branch palmarly or plantarly.
Ultrason of this region is very rewarding, and
injuries of the SDFT or sesamoidean ligaments are
generally easily defined and identified.

Injuries of the DDFT and/or manica flexoria of
the SDFT result in a swelling of these structures above
the level of the sesamoids, which are, again, cli-

cinally indistinguishable. Ultrasound of this region
is more challenging, and a definitive diagnosis can-
not always be made on ultrasound examination;
usually there is an index of suspicion based on ul-
trasound, but further imaging is often required, par-
ticularly in the case of linear tears of the DDFT.14,15
Contrast DFTS radiography is a useful addition and
will often identify damage to the DDFT or SDFT
manica flexoria.16 Ultimately, magnetic resonance
imaging (MRI) examination or diagnostic tenoscopy
is often required for a definitive diagnosis of injury
to these structures.
Palmar annular ligament (PAL) injuries are relatively rare in racing Thoroughbreds. There are generally two specific presentations. One is the acute onset overstrain type injury, with an obvious ultrasonographic region of decreased echogenicity corresponding with a sudden onset region of heat swelling and pain. Alternatively, PAL syndrome is where a combination of digital flexor tendon sheath pathology results in a generalized PAL desmopathy, resulting in thickening of the PAL.

Curb

In the past, particularly in the author’s Australian practice setting, all curbs were diagnosed predominately on clinical findings of plantar hock swelling and assumed to be overstrain injuries of the long plantar ligament. They were treated with anti-inflammatory and turned out for approximately 12 weeks. More recently, over the last 15 years, ultrasound has been of great benefit to investigate curb swellings. It allows the injury causing the swelling to be identified as an overstrain of one of the following structures: plantar ligament, SDFT, or DDFT. Those with an obvious disruption of fibers and a core lesion of any of these structures will typically be managed with anti-inflammatories and 12 weeks of rest unless the injury is severe, in which case a follow-up ultrasound is advised. Not all curb swellings have obvious damage to the above structures, but some are instead caused by a peritendinous and periligamentous soft tissue swelling and or hematoma in the region of the plantar hock. In addition, many of these cases have an obvious thickening of the plantar tarsal fascia on ultrasound examination, along with the subcutaneous tissues. These cases can be managed with a shorter duration of rest, with only 6 weeks out of training. However, they should be carefully monitored in the first 1–2 weeks for a recognized but uncommon complication of bacterial infection.

3. Additional Regions Commonly Investigated with Ultrasound

Carpal Sheath

Swollen carpal sheaths are primarily investigated radiographically; however, ultrasound provides an important adjunct when radiographs fail to identify the more common causes of carpal sheath effusion, which include fractured accessory carpal bone, radial osteochondroma, or caudal radial physeal spikes. Careful evaluation of the accessory ligament of the SDFT, radial head of the DDFT, and the intratendinous parts of SDFT and DDFT tendons and musculocutaneous junctions is often rewarding, identifying primary pathology of these structures. It is a difficult region to scan given that the typically used tendon probe (7–10MHz linear) fails to image the whole sheath in cross section and needs to be used in a systematic technique. The region is often best scanned with a combination of linear and a large convex probe if available and both weightbearing and non-weightbearing. Many cases ultimately require MRI or diagnostic tenoscopy to confirm and potentially treat pathology identified on radiographs and ultrasound.

Ultrasound can be a useful diagnostic in a variety of other less-commonly affected synovial structures, including calcaneal bursa, biceps bursa, extensor tendon sheaths, and tarsal sheaths.

Joint Injuries

Ultrasound is occasionally used to better define soft tissue injuries within a variety of joints, the most common being the fetlock or stifle joints. In the fetlock, it allows assessment of dorsal synovial pad pathology, particularly as a preoperative assessment of a chronic thickened joint and planned removal of thickened and torn dorsal synovial pads. Dorsal lateral or medial capsular tears are also not uncommon and can be imaged with ultrasound. Lameness localized to the stifle joint where there is no obvious radiographic pathology is an indication for a thorough ultrasound examination prior to or in combination with a diagnostic arthroscopy. This may change with an increase in availability of MRI or computed tomography suitable to the stifle imaging.

Muscle Injuries

The most common muscle injuries in the author’s practice setting involve the hamstring muscles in the hind limbs and brachiocephalicus or biceps muscles in the forelimbs. Ultrasound is commonly used particularly in the hamstrings to define the degree of pathology. Regions of altered echogenicity and muscle structure represent inflammation, fibrosis, and tears in the muscle tissue. Ultrasound findings can help determine acute tears with obvious loss of structure and limited fibrosis compared with the more chronic fibrotic changes. Although relatively rare, some horses are identified with a generalized chronic fibrosis of the hamstrings associated with a change in action or poor performance. These cases typically are not obviously lame, are generally 3-year-olds or older, and a hamstring provocation stretch will often elicit a lameness response.

Pelvic Injuries

With pelvic injuries, ultrasound has been well described as a useful adjunct to other diagnostics, including rectal exam, radiographs, and scintigraphy. For stress fractures of the iliac wing or displaced fractures of the ilium, ultrasound is used to map the contour of the iliac wing and shaft to identify disruptions to the normal bony surface of the pelvis. Ultrasound investigation of the coxofemoral joint can be useful but does not replace quality radiographs of the coxofemoral joint.
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Neck/Back Injuries

Ultrasound is often used as an additional imaging modality for further investigation of neck and back pain. In the author’s practice, ultrasound is used typically after a clinical exam, scintigraphy, and radiographs have defined the region of pain and bony pathology. Ultrasound aids assessment of the soft tissue structures of the back, such as the dorsal spinous ligament, and also allows assessment of the facet joints of the back and neck in conjunction with, or in addition to, the radiographic and scintigraphic findings. It is also useful to aid treatment with ultrasound guidance for medication of facet joints and or impinging dorsal spinous processes. Ultrasound guided joint injections are not just limited to the back and neck; the technique is also being used in a number of other synovial structures, including the coxofemoral joint, shoulder, elbow, biceps bursa, and navicular bursa.

4. Conclusion

Ultrasound imaging is the mainstay diagnostic for investigation of tendon and ligament injuries in racing Thoroughbreds. Its application in this role is influenced by the history and clinical findings, with careful application of ideal timing and technique to maximize its value. In addition, ultrasound has evolved in Thoroughbred racetrack practice to be used commonly in a number of other areas as a standalone or complementary diagnostic, particularly to investigate tendon sheaths, curb swellings, joints, muscle, pelvic, and back injuries.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Suspensory Ligament Ultrasound in the Sport Horse Pre-Purchase Exam

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1. Introduction

Suspensory-ligament desmitis is a common finding in sport horses of all levels. Sport horses can exhibit suspensory-ligament desmitis in many forms. A successfully competing sport horse may experience a chronic, slight decline in performance or may experience an acute, career-compromising injury. Due to the common occurrence of suspensory-ligament injury in sport horses, it has become commonplace to perform ultrasound surveys of the suspensory ligament during a pre-purchase examination. Therefore, it is vital to the success of a thorough pre-purchase exam, that the practitioner has a solid understanding of evaluating the suspensory ligament clinically and with imaging modalities. It is this combination of information that is used to advise the prospective buyer of the perceived risk involved. Implementing a consistent protocol for obtaining information related to the suspensory ligament provides the practitioner with valuable information in forming an overall opinion of the suitability of the horse for its intended use. Additionally, a survey of the suspensory ligament can be a useful documentation of what the baseline findings are as the client prepares to obtain a new horse.

2. Pathophysiology

Understanding the relationship between the clinical picture and the ultrasound examination is the key to an accurate evaluation of the suspensory ligament in the sport horse pre-purchase exam. It is essential to the interpretation of the ultrasound findings, that the horse has been thoroughly examined through palpation of the limbs and dynamic observation. Evaluating and documenting the conformation of the horse is also an important piece of information to aid the practitioner in effectively interpreting the ultrasound findings. Horses that are conformationally predisposed to stresses in the suspensory ligament may present with more fiber pattern abnormalities than a horse with proper conformation for sport. It is important to remember the suspensory ligament is a modified muscle. Therefore, the amount of muscle fibers in the suspensory ligament varies between horses. The function of the suspensory ligament is to support the fetlock joint during weight bearing. A complete survey of the entire suspensory ligament includes the origin to the insertion on both sesamoids; including the bone/ligament interface at the origin and insertion is a necessary part of the survey. Due to the variable age of sport horses being evaluated, it is not uncommon to have multiple findings in the sus-
pensory ligament during a pre-purchase ultrasound exam. Therefore, it is imperative to evaluate the entire length of the suspensory ligament in both the transverse and the longitudinal (long-axis) planes. Information obtained on the transverse view allows the practitioner to evaluate ligament edges, structure, and cross-sectional area (CSA). Information obtained on the long-axis view evaluates fiber pattern. It is important to note that lesions are usually identified in both planes, unlike artifacts that are usually noted in one plane. Visible scar tissue commonly develops at 3 to 6 months post injury, and is appreciated as hyperechoic lines with a short length when scanning in the long-axis view.

In the transverse view, focal hyperechoic regions indicate scarring in the suspensory ligament. Calcification in the suspensory ligament may also appear about 6 months post injury, and will appear as a hyperechoic area casting an acoustic shadow beneath. Although the clinical exam is of utmost importance in the pre-purchase exam, swelling at the origin is often difficult to appreciate due to the location of the suspensory ligament between the splint bones. Evaluation with ultrasound can provide valuable insight to the ligament’s integrity in this location. One benefit to using the CSA measurements in the pre-purchase exam, is the determination between a suspensory ligament with more muscle and fat fibers versus a lesion. A normal suspensory ligament may have areas of hypoechoegenecity but a normal CSA. An abnormal ligament will have areas of hypoechoegenecity and an abnormal CSA.

3. Materials and Methods

One of the most challenging aspects of the pre-purchase ultrasound is the inability to properly prepare the horse. The majority of clients are not willing to allow you to clip the limb to the best of your ability so as not to draw attention to the limb in the future. Fortunately, many high-level sport horses are kept impeccably groomed, and the hair is routinely short. Additionally, the inability to sedate the horse can also be challenging. It is not uncommon for the horse to be currently competing in an Fédération Equestre Internationale (FEI) setting and therefore cannot receive medication. In the transverse view, the suspensory origin is imaged before the suspensory can be visualized separating from metacarpal 3/metatarsal 3 (MC3/MT3). This location has the suspensory origin fibers. The forelimb origin shape will be bilobed compared to the hind limb’s triangular shape. Taking measurements in the pre-purchase exam is highly variable and controversial, but it has benefits. The CSA in warmbloods is highly variable and larger than other breeds. Again, this should be evaluated in conjunction with the clinical picture. If using the CSA measurements in a pre-purchase ultrasound exam, it is useful to compare limb to limb. However, this may add to some confusion considering that bilateral suspensory desmitis is common in sport horses. Many publications report the forelimb origin CSA to be 80 to 100 mm² and the hindlimb origin CSA at 80 to 100 mm². The practitioner must take into account the size of the horse being evaluated as it is not uncommon in sport horses to see normal suspensory origins of the forelimb with a CSA approximately 120 mm² and a hindlimb origin CSA approximately 150 to 180 mm² CSA. The body of the suspensory ligament is commonly reported at 80 to 100 mm² in the forelimb and 100 to 120 mm² in the hindlimb; however, typical sport horses often range from 120 to 150 mm². Note that the body of the suspensory should be the same throughout, and may be larger than the origin. After the bifurcation, the CSA is reported to be 60 to 80 mm², but is commonly 100 mm² in the sport horse. The suspensory branches should be oval shaped and have a very defined edge. Loss of edge definition can denote chronic stress. The insertion of the suspensory branches will be larger than the more proximal aspect of the branch. The insertional CSA is reported at 100 to 120 mm² and is commonly 130 mm² in the sport horse. The medial and lateral branches should be of similar size. The suspensory ligament insertion should be imaged where the entire ligament inserts into the bone. When using the CSA in the pre-purchase exam, it is helpful to compare the measurement of the CSA to the vertical width in the long-axis view. These measurements should be similar, and are easily compared in the split-screen views. Other views to consider include oblique views of the forelimb suspensory origin and the flexed view. Many forelimb lesions occur on the medial aspect of the ligament, so obtaining images that are oblique will completely image the suspensory origin in the forelimb. Imaging the suspensory origin in the flexed view will evaluate the bone more efficiently.

4. Conclusion

The sport horse pre-purchase exam has become more complex with more information provided to the buyer to help them reach a decision. Ultrasound of the four limbs has become the standard of practice in a sport horse pre-purchase exam. This exam is used as a reference point and although ultrasound is highly variable depending on patient and operator, implementing a consistent method of examining the suspensory ligament, can provide the practitioner much-needed information. Using measurements to compare one limb to another while relying on fiber pattern information from both the transverse and long axis, the veterinarian can provide a solid baseline of the integrity of the suspensory ligament at the time of the exam. With this valuable insight, the practitioner can use this information in conjunction with the clinical findings to develop a more accurate impression of the sport horse during the pre-
purchased exam. The most significant key point is that the ultrasound exam is a tool to help the practitioner develop an overall opinion and should not supersede the clinical impression, as well as the horse’s current performance.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.

References and Footnote

*Steele JR. (personal communication) 2007.
Clinical, Diagnostic, and Therapeutic Considerations for Management of Suspensory Ligament Branch Injuries in Sport Horses

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1. Introduction
Injuries to the suspensory branches (SBs) are common in sport horses. There are a broad variety of clinical presentations. A careful clinical exam coupled with diagnostic imaging can help in diagnosis and characterization of the injury. There are no standardized therapies or rehabilitation schedules for SB injuries. The purpose of this article is to review anatomy, pathology, diagnostic nerve block patterns, imaging, and widely used management techniques and therapeutic modalities.

2. Anatomy
The suspensory ligament originates at the palmar aspect of the metacarpus (metatarsus) and continues distally. At the juncture between the middle and distal third of the suspensory ligament, it bifurcates to a medial and lateral branch, inserting onto the medial and lateral sesamoid bones, respectively. Distal to the sesamoid bone, the suspensory apparatus consists of three distal sesamoidean ligaments (intersesmoidean ligament, oblique sesamoidean ligaments, and straight sesamoidean ligament).

The palmar/plantar recess of the fetlock joint comes in direct contact with the distal aspect of the SBs. This close anatomical proximity can affect response to intra-articular anesthesia and allow for arthroscopic visualization of the SBs.

The suspensory ligament is comprised primarily of linear arrays of type 1 collagen fibers. The fiber architecture is mixed between linear and oblique orientation. In this way, different fascicular elements come under tension at various angles of extension and flexion. Fascicles are separated by a thin fibrous septa. The ligament is encapsulated by an epiligament acting as a capsule.

Functionally, the suspensory ligament prevents hyperextension of the fetlock joint and provides medial and lateral stability. The suspensory ligament also functions to conserve energy during locomotion. Compared with the suspensory body, the branches contain little or no muscular tissue. Lavagnino
et al.\textsuperscript{1} describes heterogeneous strain patterns of the suspensory apparatus, with SBs exhibiting significantly more strain than the proximal and body at all levels of tensile force.

### 3. Clinical Examination

The superficial location of the SBs makes them relatively easy to inspect visually. In an acute injury, there is typically regional swelling, heat, and fetlock joint swelling. In more chronic cases, the swelling is often more specific to the area of injury. Chronic injuries are often accompanied by concentric layers of scar tissue, which are often easily discernible on visual examination (Fig. 1). Careful palpation of the branches seldom elicits a pain response in a normal SB. Therefore, a pain response to direct palpation of an SB is highly suggestive of injury. However, some horses with primary fetlock joint pain will have a pain response when the SBs are palpated.

In the hind limb, Ross and Dyson\textsuperscript{2} describe a higher incidence of digital sheath effusion than in the forelimbs. In many cases, the assessment of this pain response plays a pivotal role in determining whether pathology identified on an ultrasound is clinically relevant or not.\textsuperscript{3} Obvious pathology detected during clinical exam and ultrasound may not be the current source of lameness. For this reason, the clinician should pay attention to the entire suspensory apparatus, fetlock, and sesamoidean ligaments.

### 4. Diagnostic Anesthesia

There is no single nerve block technique specific to the SB. Previous reports describe SB anesthesia following palmar digital nerve anesthesia and abaxial sesamoid nerve anesthesia.\textsuperscript{4,5} In addition, some horses with SB injury responded to intra-articular anesthesia of the fetlock joint.\textsuperscript{6} Traditionally, a low 4-point nerve block will consistently anesthetize the SBs; however, the resultant region of anesthesia can be highly variable, blocking up and through the carpus/tarsus. Finally, anesthesia of the sesamoidean nerve may be specific to the proximal sesamoid bone and distal SB.\textsuperscript{7}

### 5. Diagnostic Imaging

#### Radiography

When the area of concern has been localized to the SB region, a fetlock radiographic series should be performed. In some horses, apical sesamoid pathology can be identified. The distal aspect of the splint bones should be visualized for fractures. Dystrophic mineralization of the SBs may also be identified. Additionally, because of the lack of specificity of nerve blocks in this region, radiographs can help rule out some of the other causes of lameness that may not be identified during the ultrasound examination.

#### Ultrasound

Ultrasound is generally an essential part of SB injury diagnosis. It can also be used to monitor healing over time and aid in development of the practitioners’ rehabilitation plan during healing.

The normal sonographic anatomy of the SBs can be best divided into proximal, mid, and distal inser- tional regions of the SB (Fig. 2A). The proximal branch is seen at the level of the button of the splint bone or just distal to it. At this level, the ligament has a round to oval shape, with a homogenous echogenicity and mostly linear fiber pattern. It is possible to see a mildly irregular fiber pattern at this level, as not all fibers run parallel within the origin of each branch of the suspensory ligament. The location for evaluation of the mid-SB is located just a few centimeters distal to the proximal branch region. It remains oval in shape at its superficial aspect and more triangular at its more distal extent. It has a homogenous echogenicity and a linear fiber pattern. The insertional portion of the suspensory branch is more triangular in shape, with the distal portion of the ligament inserting onto the smooth, abaxial surface of the proximal sesamoid bone. One should notice that there is a small recess in the fetlock joint that is adjacent to the dorsal and axial aspect of the suspensory branch. In instances of severe fetlock joint distention, this recess can be seen to also extend superficial to the suspensory branch if the practitioner is careful to apply minimal pressure, and this finding should be considered in interpretation of the ultrasound image. Common artifacts include a linear hypoechoic artifact due to an anatomical fold in the distal suspensory branch. It is also easy to create off-incidence beam artifacts along the axial portion of the liga- ment (especially in a transverse scan) that should not be confused with a hypoechoic lesion (Fig. 2B).
Careful scanning in both transverse and longitudinal sections is helpful in distinguishing between an actual injury and an artifact.

Sonographic appearance of SB injuries can be variable in appearance (Fig. 3). A central hypoechoic to anechoic area accompanied by fiber tearing on longitudinal views is indicative of significant injury; however, this cannot always determine the acute or chronic nature of the injury. Perhaps a better indication of disease chronicity is concentric periligamentous fibrosis or, in some instances, dystrophic mineralization within the ligament. Injury can happen at any level of the branch and can be either focal or diffuse in nature. In some instances, an increase in cross-sectional area is associated with injury. Injury at the insertion of the SB is commonly associated with bony changes to the sesamoid bone (including bony irregularity and avulsion-type injuries). Non-weightbearing ultrasound examinations can sometimes be helpful in determining the extent of linear hypoechoic-type injuries. It can also sometimes be helpful in cases where the fetlock joint communicates with a tear in the SB. Although small, focal hypoechoic lesions may not be clinically significant, it is less predictable if “wear and tear” type injuries (characterized by reduced

Fig. 2. A, Normal sonographic appearance of the suspensory branch at three levels. The proximal branch demonstrates a round to oval shape. The mid branch is oval with a more triangular shape axially. The insertional branch is triangular in shape and the abaxial surface of the sesamoid bone is smooth and regular. A mostly linear fiber pattern is seen at each level. B, Common areas of sonographic artifact/misinterpretation. a, Sonographic image of the suspensory branch insertion. The image on the left is using proper on-beam scanning technique. The image on the right is at the same level of the same branch, but there is off-incidence beam angle artifact along the axial portion of the ligament that should not be confused with a hypoechoic lesion. b, Linear hypoechoic artifact (white arrow) due to a normal anatomical fold in the distal suspensory branch.
definition of the superficial border, and a diffusely heterogeneous echogenicity) are the source of lameness.

Serial ultrasound examinations are key to mapping healing over time and determining appropriate progression of the rehabilitation program. With healing, one expects a reduction in cross-sectional area, an increasingly homogenous echogenicity, and a more linear fiber pattern, although complete sonographic resolution and return to a completely normal appearance is not necessarily expected (even with a return to full athletic performance). Elastosonography and Doppler have both been used in suspensory branch ultrasound; however, their clinical significance and impact on injury prevention or mapping of healing remains yet to be determined.8

Magnetic Resonance Imaging
In recent years, magnetic resonance imaging (MRI) has become accepted as the gold standard for diagnosis of lameness localized to the fetlock region.9 MRI allows for tissue characterization of bone and soft tissues, as well as detailed cross-sectional anatomy. This allows for the most accurate diagnostic information available. However, due to financial and practical constraints, MRI is usually used only when radiographs and ultrasound are not able to provide sufficient information. High field magnets provide greater field of view as well as more detailed cross-sectional anatomy. However, high field systems require general anesthesia. In a growing number of practices, low field (standing) MRI is used to image the fetlock region. Many horses tolerate this procedure under light sedation (versus general anesthesia). Standing systems rely on patient compliance and minimal motion artifact.

6. Pathophysiology*
When considering how to best treat and manage an SB injury, it is worth reviewing the pathophysiology of SB injury. With a better understanding of the process of injury and healing, the practitioner can make better informed decisions about the many new therapeutic options facing the profession.

With microinjuries, there is collapse of the interfascicular tissue located between collagen fascicles, which contain the linear vascular supply of the ligament. Repetitive mechanical tensile forces sustained during work affect the collagen fascicles and the immediately adjacent longitudinal vascular bed. Mechanical stretching over prolonged periods of

Fig. 3. Sonographic appearance of suspensory branch injuries.  A, Core type lesion with corresponding fiber tearing.  B, Insertional injury with associated sesamoid bone irregularity.  C, Diffuse injury characterized by heterogeneous echogenicity and diffusely irregular fiber pattering.  Also note significant periligamentous thickening.  D, A hypoechoic split in the distal branch.  Also note the irregular superficial border of the branch.
time results in accumulative damage to both structures, leading to fascicle swelling and edema. Repetitive stretching of both the vessels in the vascular bed and type-1 collagen fibrils in the adjacent collagen fascicles predispose to vascular leakage and edema. This results in ischemia of the fibrocytes in the fascicles. Although some of the normal linearly-arranged fibrocytes in the collagen fibers that undergo ischemia may make an attempt at repair by proliferating as longitudinal cellular chains of fibrocytes, most fibrocytes will either die or undergo metaplasia to form chondrocytes. As metaplastic chondrocytes, these altered former fibrocytes can survive for a short indefinite period before their death, living by anaerobic means. However, the metaplastic chondrocytes cease maintaining type-1 collagen fibers that provide the tensile strength of the ligament. Just as importantly, these neochondrocytes produce and embed themselves in islands of proteoglycan that, in turn, imbibe water. Water retention adds to the swelling and pallor of affected areas of granulation tissue. Leading to loss of tensile strength, edema, soft tissue swelling, and pain. A chondroid matrix of necrotic chondrocytes such as nodules of dead fat have more saturation sites for calcium than viable bone tissue, and this density is recognized by various imaging modalities in some chronically damaged ligaments and tendons. Medical interventions target reduction of edema and improve circulation, which allows for better adaptation of the extracellular matrix (ECM).

Nature attempts focal ligament repair by sending a new linearly oriented vascular bed into the focal areas of swollen, pale, acellular fascicles. These swollen acellular fascicles at this time only contain disorganized fragments of type-1 collagen fibrils and tropocollagen molecules. The new replacement vascular bed arises from larger arterioles in adjacent viable interfascicular soft tissue distal or proximal to the area of ischemic damage. These small arterioles penetrate the ischemic lesion and attempt to heal the defect with granulation tissue of type-3 collagen. Pericytes in the outer wall of these penetrating vessels proliferate centrifugally to form a cylindrical perivascular cuff of fibrocytes. Fibrocytes arising in this perivascular cuff of granulation tissue form a neocollagen fascicle of type-3 collagen fibers.

Histological sections of the healing lesion find an intermingling of normal collagen fascicles of type-1 collagen bordered by normal, longitudinally oriented vessels intermingling with the longitudinal fascicle of granulation tissue.

A mechanical disparity is created at this healing interface when fascicles of type-1 collagen fibers that have a 3% warp (i.e., minor elastic capacity) interface with fascicles of type-3 collagen fibers that have no capacity for minor stretch. Histopathologic observations in reinjured suspensory branch specimens and superficial digital flexor tendinitis of horses are similar. Importantly, in some studies with specimens of lesions of an 18-month duration, no remodeling of type-3 to type-1 collagen was evident at the scar tissue interface.

7. Treatment of Suspensory Branch Injuries

A number of parameters should be considered when discussing treatment options, including the following:

1. Acute vs. chronic active
2. Severity of injury
3. Degree of lameness
4. Expected level of work
5. Financial constraints
6. Time constraints/urgency

The fundamental components of the SB are the following: (1) structural proteins or ECM comprising the vast majority of the ligament (type 1 collagen); (2) living cells within the ligament, largely comprised of fibrocytes which produce the ECM and/or pericytes; and (3) nonstructural proteins, including growth factors and signaling molecules. These nonstructural proteins either reside within the ECM and are released when the ligament is challenged, or they are released from fibrocytes when the fibrocyte has been stimulated. These three components (ECM, living cells, and signaling molecules) interact in a process that has been called “dynamic reciprocity.”10 Each component is independently essential for tissue healing and tissue remodeling to occur. The release of signaling molecules from stressed ECM or stressed fibrocytes will signal fibroblasts to produce more ECM and initiate an entire regenerative cascade. Most regenerative interventions aim to modulate or enhance this process. One regenerative strategy is to inject extrinsic signaling molecules (platelet-rich plasma [PRP], interleukin-1 receptor antagonist protein [IRAP], amniotic derivatives, bone marrow derivatives, and alpha-2-macroglobulin) into the injured area. Alternatively, live cells can be introduced into the area that are intended to reinforce the existing fibroblasts. Increasingly, combination therapies (cells + growth factors + ECM) are being used on human patients with encouraging results. Lastly, high-energy laser therapy is aimed at stimulating fibroblast function in addition to improving fiber alignment and tensile strength.

Currently, in equine sport horses, regenerative treatments and rehabilitation strategies are a combination of these techniques. Many of these techniques have been directly extrapolated from use in human athletes, although the use of regenerative therapies in humans remains controversial in the sports medicine realm.

With a major disruption of the ECM (core lesion) the surrounding tissue must also “clean up” the necrotic and vascular debris resulting from
cell death, ischemia, and/or hematoma/exudate. Most physical therapeutic modalities target the removal of edema/hematoma to minimize ongoing ischemia. In doing so, the tissue physiology theoretically is augmented, resulting in well-aligned type-1 collagen fascicles and decreased cellular metaplasia.

With a large core lesion, the SB may be surgically “split” to allow extrusion of the exudate. With debris reduction, further vascular compromise is minimized. More recently, some surgeons may use phacoemulsification (TenX) for removal of necrotic and inflammatory debris. For pathology involving the axial aspect of the SB, some surgeons recommend fetlock arthroscopy. Generally, though, arthroscopy is reserved for cases that respond to intra-articular fetlock anesthesia and are refractory to conventional therapies.

Extracorporeal Shock Wave Therapy
Shock wave therapy (ESWT) is used widely for the treatment of acute and chronic SB disease. Proposed mechanisms of action include analgesia, facilitation of lesion decompression, and stimulation of paracrine secretion of fibroblasts to stimulate healing. ESWT is widely considered to be a safe and efficacious treatment of SB pathology. The author’s practice routinely uses ESWT, particularly when the sesamoid bone is involved.

Laser Therapy
Laser therapy appears to have multiple effects on soft tissues, including analgesia, enhancing lymphatic and vascular circulation, and enhancing cellular function. Laser therapy has been used extensively for treatment of soft tissue lesions in humans and horses. Recent advances in technology have allowed for more energy to be delivered with multiple laser wavelengths and various protocols. High-energy laser therapy is thought to increase fibroblast numbers and fibroblast function. Laser also appears to have an analgesic effect in some patients. A recent study involving 150 sport horses with soft tissue injuries demonstrated reduced lameness scores and improved ultrasonographic appearance following high-energy laser treatment.

8. Regenerative Therapies
A broad range of regenerative options exist from which the clinician may choose. Unfortunately, there is no Food and Drug Administration-approved product for SB treatment. Additionally, studies that compare safety and efficacy do not currently exist. As a practitioner, one must make choices about regenerative options based largely on personal experiences, small noncontrolled studies, interpersonal references, and anecdotal evidence. There continues to be debate as to if/how stem cells actually turn into the desired tissue. More recently, the “niche” or environment surrounding implanted stem cells is thought to affect the function of these cells. Regenerative therapies rely on paracrine molecular signaling to play a central role. In addition, studies suggest that a high number of mesenchymal stem cells (MSCs) may result in higher risk of adverse events and overall lower efficacy at early time points in poorly vascularized implantation sites. Also, (fresh) cells may be more effective than cultured cells. Detailed discussion of the growing number of signaling molecules and their effects is beyond the scope of this paper.

Platelet-Rich Plasma
At the time of writing this article, the use of PRPs is used widely and accepted as safe and effective. Recently, platelets have been shown to have powerful antimicrobial properties. However, isolation of equine platelets is more challenging than isolation of platelets in other species due to variable equine hematocrit levels. Furthermore, there is a high degree of variability between PRP-producing systems. Red blood cell and white blood cell numbers in PRP will likely impact tissue response. The platelets that are injected are either lysed before injection or they degranulate after injection, releasing numerous signaling agents. Care must be taken when injecting platelets intralesionally, as it has been the author’s experience that injecting too high a volume/number into a lesion leads to an adverse response. It should be noted that there is no known optimal dosage of platelets. The clinician should not force PRP into the lesion. Also, a common practice among human sports medicine practitioners is to avoid the use of nonsteroidal anti-inflammatory drugs (NSAIDS) following regenerative therapies, including PRP. NSAIDS compromise platelet function and are thought to mitigate the tissue response following PRP injection. In the human patient, some degree of discomfort is expected initially, with benefit of the treatment anticipated in 4–6 weeks. In contrast, many equine practitioners prescribe NSAIDS following PRP injection and expect a shorter time interval before realizing the benefits.

Bone Marrow as a Source of Stem Cells and Other Factors
Equine bone marrow can be harvested from the sternum or the ileum. Bone marrow contains relatively large numbers of MSCs, platelets, and a broth rich with growth hormones. Some clinicians only use the noncellular fraction to inject into lesions. Others submit bone marrow for culturing and expansion before injections. Hall reports a good prognosis for return to racing following treatment with intraslesional bone marrow aspirate. Similarly, Herthel reports favorable response with whole bone marrow aspirate. It has been the authors’ experience that in a small number of cases, injection of cultured cells can elicit an undesirable proliferative response in the area treated.
Other Sources of Stem Cells and Protein Concentrates

Dental pulp cells, adipose-derived stem cells, umbilical cord blood, and bone marrow-derived stem cells represent various sources of MSCs. Their mechanism of action on treated tissues can be classified as direct, as the paracrine effects of MSCs are directly responsible for altering the inflammatory state and stimulating the creation and remodeling of new tissue.

IRAP, PRP (i.e., Prostride), and amniotic membrane–based products represent autologously derived protein concentrates of varying concentrations and specific protein content. IRAP is a powerful anti-inflammatory agent capable of directly blocking interleukin-1 signaling. PRP-based and amniotic membrane–based products are enriched sources of platelet-derived growth factors and scaffold proteins capable of stimulating cell proliferation and tissue remodeling.

Regenerative therapies, although in their infancy, hold great promise for improving case outcomes. Comparative studies investigating clinical effectiveness and safety are needed.

9. Rehabilitation Strategies

Common Practices Treating Human Athletes

Common practices used to rehabilitate human athletes may be worth reviewing as we look to improve our strategies in treating horses. Ligament injuries are among the most common causes of musculoskeletal joint pain and disability in human sports medicine. Ligament injuries create disruptions in the balance between joint mobility and joint stability, causing abnormal force transmissions throughout the joint resulting in damage to other structures in and around the joint. Osteoarthritis typically can be a long-term consequence of nonhealed ligament injury.

Ligament injuries in people heal through three sequential phases: the “acute inflammatory” phase, the “proliferative or regenerative” phase, and the “tissue remodeling” phase. Despite advances in therapeutics, many ligaments do not regain their normal tensile strength and elastic properties.

Inflammatory Phase—Acute (Human)

The inflammatory phase follows trauma and lasts for 3–5 days, depending on the severity of the injury. Immune modulators are released that produce pain, and there is often micro- or macrohemorrhage in the tissues. This, together with debris from damaged cells, produces swelling within the ligament, putting pressure on nerve endings, and creating more pain.

Rehabilitation time can be reduced by appropriate treatment in the acute stage. This consists of protecting the injured anatomy from further damage (e.g., the use of crutches, casting, or splinting–immobilization), rest from activity involving the injured part, ice, compression, (pressure gradient) elevation, and the administration of anti-inflammatory medication (short term).

Regenerative Phase—Subacute (Human)

The regenerative phase is mediated by blood clotting over the damaged tissue and occurs between 3 to 21 days. Platelets form a mesh to initiate healing. The use of electrotherapy in this phase has been shown to encourage fibroblast activity that ultimately provides a structurally stronger ligament.

Remodeling Phase—Chronic (Human)

The remodeling phase can last for up to a year. It involves maturation of collagen tissue from type 3 to type 1 and realignment of collagen tissue. When it is first laid down, the collagen tissue is haphazard and possesses little tensile strength. The ligament gradually becomes stronger through being subjected to controlled strain in a functional pattern, which stimulates longitudinal fiber alignment. Physical therapy, in the form of controlled exercises progressing to functional activity, aids this process of remodeling.

Because the remodeling phase lasts for up to a year, there is a potential weakness in the ligament and a risk of reinjury. During this time, risk is reduced by providing additional stability with external taping or bracing; increasing the strength of muscles, which also provides support to the joint; and by doing proprioceptive exercises to increase the patient’s sense of joint positioning.

New advances have been used in improving human ligament healing after injury or surgery. One of the most important advances has been the early implementation of controlled exercise to stimulate repair and restoration of function. It has been found that the treatment of ligament injuries with prolonged rest may delay recovery and adversely affect the tissue repair.

With human ligament injuries, physical therapy is used to improve soft tissue quality and regain joint function and stability. Specialized rehabilitation programs (therapeutic exercise) can target the muscles and tendons around a joint to provide more stability and strength. Coordination training is also helpful to regain control and agility.

Ligament healing can be slow and often incomplete. Associated joint laxity improves slowly over a period of six weeks to a year. There is a continual assessment and reassessment throughout the entire process with an athlete’s return to sport. Orthopedic surgeons have attributed up to 70% or more of their success of their surgical interventions based upon the physical therapy plan of care implemented postsurgery. Therapeutic regimes for horses with ligament injuries may have parallel goals.

Various therapeutic physical agents on the market today offer options to treat the following conditions. Below are some of the more common modalities in use by practitioners in both human...
and animal rehabilitation and sport performance. It should be noted, however, that modalities in general have varied levels of scientific evidence in support of purported claims.

10. Managing Suspensory Branch Injuries in Horses

Acute Phase (Equine)
In acute stages with severe injuries, cold therapy, compression, leg wraps, topical anti-inflammatory agents, systemic NSAIDS, laser therapy, and stall confinement are recommended. Most interventional therapies are performed during the acute or sub-acute phase. It is impossible to eliminate loading of the suspensory apparatus. Although, recently, a mechanical boot has been invented that restricts fetlock drop (HorsePower). Leg wraps should be changed twice daily and the affected leg inspected. Cold therapy consisting of 20 minutes, four times a day is initially recommended. Compression cryo-boots can effectively deliver cold therapy while providing compression (i.e., Ice horse). During this time, passive range of motion exercises of the fetlock may be beneficial. The acute phase generally lasts 2–10 days. A clinical examination and ultrasound study at the conclusion of the acute phase will help determine whether the horse is ready to enter the next phase of rehabilitation.

Subacute Phase (Equine)
Once the horse can walk comfortably and the majority of tissue edema has resolved, treatment of subacute injury may proceed. Loading exercises such as prolonged walks on even footing, manual therapies such as cross-fiber massage, and tools that enhance lymphatic circulation (cross fiber massage, laser) may be beneficial. Cold therapy may be decreased to twice daily. The subacute phase generally lasts 2–6 weeks. A critical component of rehabilitation involves the retention of elasticity. In some cases where scar tissue exists with a new SB injury, the clinician must meet the contradictory needs of rest (acute lesion) and loading (maintain elasticity of scar tissue). Some horses benefit from swimming or underwater treadmill during this time. During this phase, the horse should be reevaluated monthly with careful attention to monitoring clinical status (soundness, flexion test, palpation response), as well as monitoring ultrasonographic improvements.

Remodeling Stage (Equine)
As the ligament and surrounding tissues are healing, the clinician will recommend specific strategies to incrementally challenge the tissue. In the subacute stages, the horse gradually increases walk activities, such as trotting on even footing, and is progressed to more demanding exercises as tolerated. The remodeling phase generally lasts 6–12 weeks. The focus during this phase is on returning the horse to its previous level of performance, while minimizing the risk of re-injury.

<table>
<thead>
<tr>
<th>Physical Agent Modality Options</th>
<th>Acute Inflammatory, 24–72 hrs</th>
<th>Subacute Regenerative, Days to 6 Weeks</th>
<th>Chronic Remodeling, 6–12 Weeks</th>
</tr>
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<tbody>
<tr>
<td>Ice, laser, US, TENS for pain control, relative rest, PEMF, ionictophoresis</td>
<td>Pain</td>
<td>Swelling</td>
<td>Decreased Joint ROM</td>
</tr>
<tr>
<td>Elevation, compression, ice, relative rest, laser, PEMF, high-volt stimulation</td>
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<tr>
<td>Joint mobs, active and passive ROM, control inflammation</td>
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<tr>
<td>Soft tissue mobilization, high frequency vibration, dry needling, joint mobs to release fascial restrictions, stretching</td>
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<tr>
<td>Muscle electrical stimulation, therapeutic exercise, physical training, correct biomechanics</td>
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<tr>
<td>Dry needling, soft tissue release, joint mobs, laser, US, PEMF, acupuncture electrical stimulation</td>
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<td>Neuro reeducation, therapeutic exercise, physical training</td>
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<td>Balance and coordination exercise, physical training</td>
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<td>Strengthening, muscle electric stimulation, therapeutic exercise physical training</td>
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<tr>
<td>Soft tissue mobs, joint mobs, stretching, therapeutic exercise</td>
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<tr>
<td>Joint mobilization, manipulation, stretching, active exercise</td>
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<tr>
<td>Correct joint and soft tissue restrictions, physical training, biofeedback, correct biomechanics</td>
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<tr>
<td>Trigger Points</td>
<td>Proprioception</td>
<td>Balance/Coordination</td>
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<td>Myofascial Restrictions</td>
<td>Muscle Weakness</td>
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<tr>
<td>Soft Tissue Restrictions</td>
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<tr>
<td>Joint Hypomobility</td>
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<tr>
<td>Muscle Atrophy</td>
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<tr>
<td>PEMF, pulsed electromagnetic field; ROM, range of motion; TENS, transcutaneous electrical nerve stimulation; US, ultrasound.</td>
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Table 1.
time over the course of 3–8 weeks, depending upon the severity of the injury. If this is well tolerated, the injury is clinically “quiet,” and ultrasound suggests mechanical integrity, trot can be incrementally added. In the early stages, trot can be introduced twice weekly, thus allowing ample time for tissue adaptation. If well tolerated, trot time can be increased weekly, even when trot work is only allowed every other day. Generally, the horse takes 3–6 weeks to reach 20 minutes of trotting after the introduction of trot. Once trotting for 20 minutes, many horses may return to pasture turn out if the injury is remaining stable and the ultrasound is acceptable. Additionally, many horses benefit from intra-articular fetlock therapy (IRAP/PRP) during this phase. The month following typically resembles basic dressage work every other day alternating with basic conditioning.

Chronic Active Phase (Equine)
A large proportion of competing sport horses carry some degree of chronic active suspensory desmitis. Treatment of chronic active suspensory disease is an issue of management rather than rehabilitation. Common clinical presentations of chronic active SB disease includes a positive response to the flexion test and the horse drifts (right or left over a jump, hind leg injury), stumbles upon landing from a jump (front leg), and has difficulty with upper-level movements, such as collection and extension in dressage horses. It is the author’s experience that use of regenerative therapies during the chronic phase often will offer clinical improvement. However, there is proportionally less improvement seen on ultrasound when injuries are treated in their chronic phase.

11. Discussion
SB desmitis is a common injury in athletic sport horses. Oftentimes, subclinical injuries occur and are undetected.4 As described above, chronic repetitive injury can lead to changes of tissue characteristics with increased fibrosis, resulting in reduced elasticity and increased pain when mechanically challenged. At this time, the determination of how much to mechanically challenge an SB during rehabilitation remains subjective. Additionally, using an elevated toe shoe may reduce mechanical stress on suspensory apparatus.

In horses where a single SB is injured, one must question what led to the asymmetrical loading. Dyson5 suggests that foot imbalance may be a predisposing factor. Preexisting abnormalities above or below the acute injury may also predispose a horse to unilateral suspensory branch disease. Because of its close proximity to the fetlock joint, clinical symptoms of SB disease may be confused with fetlock pathology and vice versa.

As described above, strain patterns of SBs are increased compared with the rest of the suspensory apparatus.6 Following an SB injury, formation of concentric scar tissue often ensues in the months that follow. Characteristics of the scar tissue have not been well described. It is possible that this scar tissue arises from injury to the epiligamentum which may have unique properties (Fig. 4).

It is also important to consider the unique stresses of SBs in sport horses (vs. racehorses). Sport horses are required to make rapid direction changes and a broader range of gait requirements (walk, trot, canter, extended trot, and gallop). Jumping horses must repeatedly take off and land from jumps and be able to turn quickly in variable footing. The show schedule for jumping horses is often very rigorous with minimal down time to allow for tissue recovery and adaptation. Event horses must perform dressage and jumping in addition to cross country. In the cross-country phase, event horses endure highly variable conditions. Oftentimes, footing can range from mud to sand to firm, packed surface. Additionally, event horses must gallop on course, tolerate water fences, drop fences, and must hold up to rigorous conditioning programs. In dressage horses, at the upper levels of work, the hind limbs are ideally carrying a proportionally larger load. Additionally, increases in lateral work and pirouettes require rotational stability and strength. By the time most sport horses reach the upper levels, they often have some degree of orthopedic compromise.

When examining a horse with SB desmitis, clinical diagnosis is not always straightforward. The hallmark signs of swelling and pain are paramount in making a diagnosis. However, axial injuries oftentimes do not respond to direct palpation. Additionally, many horses have more than one injury following a SB problem. Horses with SB injuries often show minimal lameness in a straight line, with lameness more apparent when lunged on a soft surface. Other horses may not show overt lameness unless the horse is ridden.
Given proper therapy and rehabilitation, many sport horses can return to their previous level of work. However, particularly with chronic active disease, recurrence of injury can occur with an increased workload (increase level of jumping, different level of eventing). Therefore, care must be taken when the workload demands increase.

Sometimes, making a complete diagnosis requires multiple steps. In a horse whose SB injury resolves but lameness persists, the clinician should block the leg again and repeat imaging. If there is no definitive answer, MRI or arthroscopy should be considered. Horses with excessive periligamentous scar tissue, surgical fenestration of scar tissue may be helpful.

Management of chronic active SB disease (CASBD) is a common practice for sport horse practitioners. The clinician should attempt to determine whether the SB is mechanically able to withstand the demands specific to the horse’s job. Widely used techniques include cold therapy immediately after work, ceramic leg wraps overnight (Back on Track, Incrediwear), intermittent ESWT therapy, and regenerative treatments into the fetlock joint. Careful attention should be made to keep foot angles consistent, particularly in the medial/lateral plane. The main goal in managing chronic active disease is to minimize further damage, maintain tissue elasticity, and remove pain. Other techniques include therapeutic ultrasound and high speed vibration therapy (Rapid Release Therapy). Clients should be made aware that competing a horse with CASBD may predispose the horse to further, potentially serious, injury. Management strategies may also include modification of work load and training schedule. Careful ongoing monitoring of the patient (ultrasound, palpation, and soundness) is critical to successful management of CASBD.

In conclusion, SB injuries can be challenging to diagnose, treat, and manage in working sport horses. Fortunately, many viable alternatives exist from which the clinician can select. In the future, uniform methods of comparing safety and efficacy of therapeutic interventions as well as rehabilitation strategies will aid the clinician in offering recommendations for therapy.

At this time, clinical decisions regarding regenerative medicine in horses are often made with limited scientific support. Most clinicians are reliant on interpersonal communications and first hand experimentation. In the authors’ opinion, an overarching strategy for bridging the gap between basic sciences research and clinical practice is needed in the veterinary industry.

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.

References and Footnotes


*Classen S. (personal communication) 2018.
How to Perform and Document an Oral Examination

Claudia K. True, DVM

Before beginning an oral examination, it is important to get a thorough history from the owner or caretaker. Questions to ask could include the following:

- Does the horse have any difficulty chewing?
- Is it dropping feed or quidding?
- Does this change depend on what it's eating?
- Does it tilt or shake its head when eating or when ridden?
- Is there a history of weight loss?
- Does it avoid contact with the bit?
- Has there been a change of bits?

If there are concerns with how the horse is chewing, this can be explored by feeding the horse hay or grain to see if the issue can be recreated. Similarly, if a horse is head tossing or is carrying its head in an unusual manner while being ridden, either watch the horse go under tack or have the owner video the behavior. It is helpful to examine the bit and bridle for fit. Evaluate the horse’s overall appearance. What is its body condition? Does its hair coat indicate it may have pituitary pars intermedia dysfunction? Does it appear to have other health issues? You may need to treat the underlying issues before performing a dental exam and any dental procedures. This is also why it’s
also important to perform a thorough physical exam on every horse before sedating for the oral examination, including listening to their heart, lungs, gastrointestinal tract, as well as taking a temperature.

Next, an external exam of the patient’s head is performed. Sedation may be required for part of the exam based on the horse’s temperament. This exam should include palpating the parotid salivary glands, lymph nodes, bony structures of the skull including both mandibles, and temporomandibular joints for swellings, pain, wounds, or drainage. The muscles of mastication should be palpated for atrophy or hypertrophy. Take note if there is skull asymmetry. Nostrils are checked for discharge and odor.

With the patient sedated, a more complete oral examination can be performed. To aid in oral visibility for the practitioner and safety of any handler, the use of a headstand or dental halter is necessary. These come in two forms: those that are hung over a beam or other overhead device or those that have a solid base. Although much of this is the practitioner’s choice, it would be of benefit to consider where most of your examinations will take place.

Sedation aids in a better examination of the lips, incisors, interdental spaces, and the mucosa that comes in contact with the bit. Incisors should be inspected for general age, number of teeth, diagonal ("slant") teeth, retained deciduous teeth, class 2 or class 3 malocclusions (overbites/underbites), and fractures or excessive wear. Also note discolorations of teeth and inspect the occlusal surfaces, noting any exposed pulp horns. Equine odontoclastic tooth resorption and hypercementosis is a painful and progressive syndrome that most commonly affects the incisors and canines. Careful inspection of these teeth can lead to early identification and management of this syndrome.

The interdental spaces should be palpated and inspected for unerupted or "blind" wolf teeth (05s), as well as a general inspection for soft tissue or bony trauma. It is not uncommon to find trauma from the bit, which could help identify the source of bit avoidance or head-tossing behavior.

Next, the speculum is placed securely so that the incisors rest on the bite plates. If a horse has a severe class 2 or class 3 malocclusion, it may not be possible to use the standard McPherson-type speculum without the use of wider bite plates. These can be purchased and interchanged with the bite plates that come with the speculum.

As with any examination, it is usually best to use a systematic approach. After thoroughly rinsing the mouth, digital palpation with a gloved hand of both teeth and gingiva should be the first step in any oral exam. This can reveal sharp enamel points, feed packing between teeth, painful gingiva, tooth elongations (e.g., hooks, waves) misalignment of teeth (e.g., linguoverision), and mobile teeth. Next, a good light source, whether it is attached to the speculum bite plate or worn on one's head, is essential to gain an overall view of the horse’s mouth (Fig. 1). Look at both the hard and soft palate, check for abrasions, lacerations, or abnormal tissue. Take note if the hard palate and arcades are symmetrical. Also, examine the tongue for any lacerations or old injuries. It is important to check sublingually not only to inspect the salivary duct openings but also to

Fig. 1. Oral light sources. On the left, the light attaches by a magnet. On the right, there are several types of light sources that are either worn around the practitioner’s head or attached to one’s glasses.

Fig. 2. Left, From top to bottom: Short combination periodontal probe and shepherd hook explorer, long-handled shepherd hook explorer, and long-handled periodontal explorer. Right, periodontal probe in use.
look for growths or foreign bodies. The buccal mucosa can also be examined at this time, but the caudal aspects of the mouth are best seen with a mirror or oral endoscope. Check the occlusal surfaces for any elongations of each tooth.

To examine the periodontium as well as the endodontium of the teeth, a mirror or oral endoscope is necessary. An in-depth look at both of these instruments is discussed in an article within this “How to” series. Starting with one arcade, closely examine the gingival tissue of each tooth. Focus on areas where mobile teeth or painful gingiva were detected on palpation. Areas of gingival recession should be checked with a periodontal probe for depth and for amount of periodontal attachment loss (Fig. 2). Areas of gingival recession are found between two teeth or along the side(s) of one tooth. Any area where food is seen packing between teeth must be carefully explored. This widened interproximal space (diastema) with food packing needs to be cleaned out with long-handed right-angled forceps and Gracey curettes (Fig. 3). A high-pressure right-angle water sprayer can be used in cleaning the diastema. Once clean, use a mirror or endoscope to check for periodontal disease and measure pocket depth with a periodontal probe (Fig. 4). A depth of 5 mm or greater is considered abnormal. Documentation of periodontal disease uses an index adopted for the horse by Klugh² (Table 1). While inspecting the periodontium, the vestibular (buccal) and lingual/palatal sides of the tooth should be examined for fractures as well as peripheral caries. Fractures involving one or more pulp horns are called complicated crown fractures and a dental explorer should be introduced to see if the pulp horn is exposed. These teeth should be radiographed to ensure there are no apical changes (bone loss, condensing osteitis, periosteal reaction, widened periodontal space, root blunting). The occlusal surfaces of all teeth should be examined for the appearance of exposed pulp horns, which typically appear lighter in color when compared with the other pulp horns (Fig. 4). A long-handed dental explorer will catch or stick if there is a defect in the pulp and if so, these teeth should be radiographed.

<table>
<thead>
<tr>
<th>Table 1. Equine Periodontal Disease (PD) Index</th>
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<tbody>
<tr>
<td>Stage</td>
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<tr>
<td>PD0</td>
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<tr>
<td>PD1</td>
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<td>PD2</td>
</tr>
<tr>
<td>PD3</td>
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<td>PD4</td>
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</table>

Fig. 4. Tooth 406 with #6 pulp horn exposure (blue arrow).
Cheek teeth infundibulae are a common site for carious lesions. A recent study in the United Kingdom found 45.5% of 706 horses had infundibular caries. The severity of the lesions can be recorded based on an infundibular grading system used by Homna and more recently modified by Dacre (Table 2).

The findings of the examination need to be meticulously documented as they are part of the patient’s medical records. Many types of dental records can be obtained free of charge online or created by the practitioner. One example can be found at the American Veterinary Dental College’s (AVDC) website. If making a chart for one’s own needs, the following should be included:

- Owner and patient information
- History
- Physical exam findings (excluding oral exam)
- Sedation type and dose
- Local, regional nerve blocks
- Notes and diagrams of findings to include:
  - Location of soft tissue injuries or abnormal tissue

### Table 2. Grading System for Equine Dental Caries

<table>
<thead>
<tr>
<th>Degree or Grade</th>
<th>Grading Evaluation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Degree 0</td>
<td>No macroscopic visible caries (can include infundibular hypoplasia)</td>
</tr>
<tr>
<td>Degree 1</td>
<td>Caries only affecting the cementum</td>
</tr>
<tr>
<td>Grade 2</td>
<td>Caries affecting cementum and adjacent enamel</td>
</tr>
<tr>
<td>Grade 3</td>
<td>Caries affecting cementum, enamel, and dentin</td>
</tr>
<tr>
<td>Grade 4</td>
<td>Caries now affects the integrity of the tooth (e.g., development of an apical abscess or secondary tooth fracture)</td>
</tr>
</tbody>
</table>

Fig. 5. A sample dental chart. This can be used on a tablet device or hand written.
To better demonstrate the location of fractures, infundibular caries, and exposed pulp horns, the use of an illustration of each arcade, viewed from the occlusal surface, is helpful. Including the DuToit Equine Endodontic Numbering System helps because the pulp horn numbers are identified (Fig. 5). In addition, the use of AVDC-approved abbreviations make recordkeeping uniform and allow the benefits of more easily sharing these records with other practitioners. Adding a legend of the most used abbreviations may help clients in reading their records.

However, one chooses to record their dental examinations, access to the patient’s history is important. This is helpful to have the previous sedation dose but also allows one to focus on areas of past concern.

3. Results
Increased diligence in performing a systematic and complete oral examination on every patient can lead to additional diagnoses of dental disease. In a 2008 study of 300 horses, a thorough endoscopic oral examination not only found sharp enamel points (96.3% of horses) and focal elongations/overgrowths (64.3%) but also identified diastemata (24.3%) and infundibular hypoplasia/caries (48.3%). Another study involved using standardized oral examination records on 471 horses. These practitioners identified diastemata in 50% of these horses, with 45% having associated periodontal disease. With early identification, periodontal disease can be treated prior to further progression. In addition, identifying other issues such as complicated tooth fractures, soft tissue growths, and caries can lead to early treatment and less discomfort for the horse.

4. Discussion
Incorporating a thorough and systematic oral examination into the author’s practice has increased the amount of periodontal and endodontic diseases identified and treated. When owners observe the exam, they tend to be more willing to treat their horse’s oral diseases. With the increased research and knowledge about equine dental disease, practitioners should be educating their clients of the benefits of regular oral examinations for their horses. Clients need to understand that the “floating” of their horse’s teeth is secondary to the thoroughly documented oral examination.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.

References and Footnotes

aSample dental chart from AVDC is available at https://www.avdc.org/Example_Equine_Dental_Chart.pdf.

bAVDC equine specific dental terminology can be found at https://www.avdc.org/Nomenclature/Nomen-Equine.html.
How to Use an Oral Mirror and Endoscope

Allison R. Dotzel, DVM

1. Introduction
As equine dentistry continues to evolve in the veterinary profession, the emphasis on visual dentistry is increasing. This concept focuses on the need to do a thorough visual examination of the oral cavity to accurately identify any pathology that may be present. The use of an oral mirror or endoscope can greatly enhance the clinician’s ability to do a comprehensive oral examination of the equine patient. Examination of the caudal portion of the equine oral cavity can be challenging due to its length, restricted caudal buccal space, and strong tongue. Use of a mirror or endoscope can help obtain a better view of the caudal oral structures and help the clinician perform a more detailed oral examination. An endoscopic system has the added benefit of providing a magnified image that can help the practitioner identify subtle pathology that may be missed during a traditional oral exam. In addition, oral endoscopy is a valuable aid to dental and oral surgical techniques, as it helps facilitate instrument placement and provides visual guidance. Oral endoscopy can improve client education and the ability to share findings with veterinary colleagues. It also allows for better and more accurate dental records as well as the collection of high-quality images for use in case reports and other publications.

2. Materials and Methods
The are several models of equine dental mirrors commercially available for purchase. The mirror is mounted on a long rigid shaft that is capable of reaching the caudal aspect of the oral cavity. The mirrors head generally ranges from approximately 2.5–5 cm in diameter and is able to be replaced if chipped, cracked, or otherwise damaged. Oral mirrors heads can be round or oval in shape. Many mirrors are sold without a prebent angle of the mirror head. In this case, the shaft proximal to the mirror head should be heated and the head bent to an angle of approximately 30–45 degrees for optimal viewing in the oral cavity. In general, smaller and thinner mirrors are better tolerated by the equine patient and can still provide good visual information. Oral mirrors can be used as cheek and tongue retractors during the oral examination.

An equine oral endoscopic system includes a waterproof, rigid endoscope that is generally 5–15 mm in diameter and 40–60 cm in length. The lens angle can vary from 60–115 degrees. A lens angle of 45 degrees works well for examination, but an angle approaching 90 degrees is more favorable for visual guidance during dental procedures. A newer model of endoscope is available that has a variable lens angle that can be adjusted incrementally from 15–90 degrees. A high-resolution digital recording device, such as a digital camera, is coupled to the
endoscope. A bright halogen or LED endoscopic light source is essential for optimal image quality. There are several equine oral endoscopic systems available commercially. Alternately, the components for the endoscopic system can be purchased separately and assembled by the practitioner.10

An effective oral examination of the equine patient begins with a well-sedated horse in a quiet environment.11 The head should be supported in a comfortable position by an equine dental halter or head stand. A full-mouth speculum is placed and all feed and foreign material is flushed from the mouth with an oral-flushing syringe or equine water pick. A bright light source is essential for the oral examination. For a mirror examination, a high-quality halogen or LED headlight or speculum light should be used. As mentioned, equine oral endoscopic systems should incorporate a bright light source coupled to the endoscope. Excessive motion of the tongue or a chewing motion can inhibit the ability to use an oral mirror or endoscope effectively. This type of movement can be minimized by intravenous boluses of detomidine HClb and butorphanol tartratec.2 Fogging of the mirror or lens of the endoscope can be problematic, particularly in cold climates. This can be managed by rinsing the mirror head or tip of the endoscope with hot water or by using an antifogging glass spray or chlorhexidine solution.1,2,8 The tip of the endoscope should not be submerged in water unless the scope is barometrically sealed. Medical endoscopes are preferred over cheaper borescopes because they are specifically designed for medical applications and thus have stronger barriers in place against fluids entering the scope. In addition, many models of rigid medical endoscopes are designed to withstand sterilization via autoclave. Rigid endoscopes are preferred for oral endoscopy over flexible endoscopes, as sharp enamel points can damage the outer surface of flexible scopes and cause them to leak.

The oral examination is performed systematically to evaluate all surfaces of the teeth as well as the surrounding soft tissues. The mirror or endoscope is first placed between the right maxillary and mandibular arcades so that the occlusal surface of 106 is in the field of view. The mirror or endoscope is then carefully advanced caudally to visualize the occlusal surface of each tooth in the arcade. When the distal aspect of 111 is reached, the mirror or endoscope is tipped to visualize the palatal aspect of 111 and then withdrawn in a rostral direction to examine the palatal mucosa and interdental spaces. When the rostral aspect of tooth 106 is reached, the mirror or endoscope is again advanced to the distal aspect of 111, tipped to visualize the vestibular (buccal) aspect of 111, and withdrawn in a rostral direction to examine the vestibular interdental spaces and buccal mucosa. When examining the vestibular aspect of the maxillary cheek teeth, it may help to loosen the stra...
abrasions/lacerations, and *Gasterophilus* larvae (Fig. 2).²

Although a thorough oral examination can be accomplished by skilled use of an oral mirror, the use of an endoscope does have added benefits. An oral endoscopic exam is more sensitive to picking up subtle oral pathology due to the magnification of the captured image. In addition, the endoscope can be used to improve visualization and to guide the placement of instruments during dental and oral surgical procedures.²⁶,⁷ For instance, endoscopy can be used during oral extraction surgery to properly seat the blades of the dental spreader in the interdental spaces, avoiding unintentional damage to the teeth or soft tissues (Fig. 3). It can also be used to assess the quality of the contact of the dental extraction forceps with the crown of the tooth to be extracted (Fig. 4). Surgical progress can be monitored by inserting the endoscope while the tooth is in the process of being manipulated to assess the tooth's...
movement. In cases with dental fragments and retained root tips or in minimally invasive buc-
cotomy procedures, the endoscope can help guide
the placement of elevators to break down the re-
main ing attachments holding the fragments in
place. Endoscopic guidance is also invaluable
for positioning and guiding the high-speed bur in
cases where it is necessary to orally section a tooth
prior to extraction (Fig. 5). The endoscope can be
used to improve visualization during assessment
and treatment of oronasal and oroantral fistulae
(Fig. 6). Finally, the oral endoscope can also be
used to explore and image the sinus during sinus
flap surgeries.

The other added benefit of endoscopy compared
with an oral mirror is the ease of recording images
and videos of oral examination findings. It is pos-
sible to obtain an image of dental pathology as
viewed with the mirror by directing a digital camera
at the mirror’s image and taking a picture (Fig. 7).6
However, the quality of this image greatly depends
on the ability of the practitioner to hold the mirror
steady while taking the picture. This process is
further complicated by patient compliance, and im-
age s tend to be of poor quality if excessive patient
movement occurs. It is much easier to position and
take high-quality photos or video recordings by us-
ing an endoscope. The small-diameter head of the
endoscope is also better tolerated by the equine pa-
tient than even the smallest and most low-profile
equine oral mirrors.

4. Discussion
Because the conformation of the equine oral cavity
makes a thorough examination challenging, it is
important to incorporate tools such as an oral mirror
or endoscope to help improve visualization, particu-
larly of the caudal teeth and soft tissue structures.
A better quality oral examination benefits the
equine patient because it allows the clinician to rec-
ognize dental disease in the early stages and to
address it before it reaches a point where it is not
reversible and necessitates extraction of the affected
tooth/teeth.6 In addition, obtaining digital images
of pathology identified during the exam, either
through mirror photography or via endoscopy, can
allow for more effective monitoring of chronic dental
conditions over time. These images can be easily
shared with colleagues for consultation and referral
purposes.1

Many equine veterinarians make an effort to in-
clude the client in their examination process to help
them understand their horse’s dental pathology.
However, because visualization of the caudal oral
cavity can be very difficult, clients may not be able
to fully appreciate the pathology that is present.
Showing clients the area of interest with the oral
mirror may further their understanding of their
horse’s dental health. Oral endoscopy is an even
more helpful tool for client education because of the
ability to project a real-time magnified image of the
oral examination on a large screen or monitor.
In general, being able to experience the oral exami-
nation in this way gives the client a better appreci-
ation for why routine dental care is important for
the health of their horse.

While oral mirrors are very affordable and within
financial reach of all equine dental practitioners, the
majority of commercially available oral endoscopic
systems have been cost prohibitive for equine veter-
inarians who practice dentistry outside of a large
hospital setting. As a result, this helpful diagnostic
aid has been greatly underused. However, if the
clinician is willing to purchase the components for
the endoscope separately, an endoscopic system that can take high-resolution photos and videos can be assembled for $2000–$2500 (USD). This type of system is highly portable and can be used both in ambulatory practice or a hospital setting.

The recent emphasis on visual dentistry and early diagnosis and treatment of equine dental conditions are important because they may allow clinicians to treat pathology and halt the progression of dental disease before it reaches the late stages. In addition, allowing the client to follow along with the examination in real time can help them appreciate the importance of regular veterinary dental examinations, which can be a great practice builder. Furthermore, oral endoscopy has the potential to greatly increase the efficiency of oral surgeries and other dental procedures, which have traditionally proved to be challenging due to the conformation of the equine oral cavity. Incorporation of these modalities, particularly endoscopy, requires an initial monetary investment and may increase the time spent working on each patient. However, improving the quality of the oral examination has the potential to greatly increase the quality of dental care and to help overcome some of the inherent challenges of equine dentistry.

Acknowledgments

Photos courtesy of Edward T. Earley, DVM, Dipl. AVDC/ Eq, and Cornell University College of Veterinary Medicine.

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes

How to Radiograph Incisors and Canines

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1. Introduction
Little has been contributed to the veterinary literature on diseases of the equine incisor and canine teeth until the last 20 years. In the past, these teeth have been used to help determine the age of horses, but their disease status has been neglected. Veterinarians have recognized fractures and avulsion injuries of these teeth especially in young colts but have not critically evaluated the injury to the subgingival portion of the involved teeth, surrounding bone, and permanent tooth buds (Fig. 1). Supernumerary incisors are often present and visible on examination and can be difficult to differentiate from retained deciduous teeth on gross crown evaluation alone. Displaced and dysplastic teeth are encountered but an evaluation of reserve crown and root position and conformation is dependent on imaging below the gum (Fig. 2). In older horses, hypercementosis and internal resorptive lesions are often seen clinically as gingivitis and caries with tenderness in this area. Radiographs are necessary to diagnose and plan treatment for this painful condition commonly known as equine odontoclastic tooth resorption and hypercementosis (EOTRH).2

Superimposition of the right-left and upper-lower arcades has made obtaining extraoral diagnostic radiographs of the incisor teeth problematic. Intraoral radiographic techniques have been perfected to make taking diagnostic radiographs of the incisor and canine teeth of the standing sedated horse possible.3–6 Canine teeth can usually be radiographed using a combination of intraoral and extraoral oblique views. The technique described in this session will make the process of obtaining high-quality diagnostic radiographs of the front teeth easy and clinically rewarding. The common use of computed and digital radiography in equine practice has made it more convenient to acquire dental images in the field. The most common problems with acquiring good quality, diagnostic films include positioning errors, exposure anomalies, movement artifacts, labeling errors, and imaging processing faults.7

2. Materials and Methods
Radiographs of the equine teeth can be obtained with most portable imaging systems commonly used in the field. Portable systems are easier to manipulate into position around the head than gantry-mounted machines. Exposure requirements are not high for dental radiographs, and conventional radiograph cassettes with rare-earth screens or computed radiography (CR) and digital radiography (DR) systems can be used. Exposure for rostral skull radiographs are less than that required for the cheek teeth and sinuses. This portion of the head has less thickness, and most of the change in settings is a reduction in kVp, with only a small reduction in mAs. Proper machine collimation in
any direction is helpful, and laser distance calibrations help to standardize the technique. Radiation safety should be strictly adhered to when taking equine head radiographs. The primary beam should be collimated to include only the area of interest, and the hands of personnel should be protected and kept as far as possible from the area. Personnel should wear lead aprons, lead gloves, thyroid guards, and dosimeters. All unessential personnel should leave the vicinity when radiographs are being taken.

Heavy sedation is required to properly position the horse and reduce head motion, thereby reducing the need for repeat exposures due to movement artifacts. A combination of detomidine hydrochlo-

Fig. 1. A and B, Photos of the incisors of a 4.5-year-old gelding with a history of an untreated jaw injury as a yearling. The right lower jaw area is displaced rostral and several extra lower incisors are present. C and D, Lateral and V-D bisecting angle radiographs of the abnormal incisors pictured above. The five most rostral incisors appear to be deciduous teeth with shorter, mature reserve crowns. Two permanent teeth are axially rotated and displaced. Two unerupted corner incisors are developing in the jaw. Two permanent incisors are not present. The lower canine teeth appear normal.

Fig. 2. A and B, Mandibular incisors of a 9-year-old gelding. The 302 and 402 appear small and have excessive crown wear for a horse of this age. A bisecting angle D-V oblique radiograph of mandibular incisors and canine teeth (R70V-CdDO [intraoral]). This view demonstrates small crown fragments of deciduous teeth and no permanent tooth in the lower 02 positions. The superimposition of the lower canines and corner incisors can be alleviated by taking 15° lateral oblique views.
ride\textsuperscript{a} (0.01–0.02 mg/kg IV) and butorphanol tartrate\textsuperscript{b} (0.01 mg/kg IV) has been found to work well. The dosage can be adjusted to the temperament of the horse. Once the horse is sedated, it is useful to have an adjustable stand to prop the head, rendering it stable and motionless. Metal objects and tack can interfere with getting good images, so nonvital headgear should be removed. Taking intraoral radiographs requires that the cassette or sensor be placed in the horse's mouth (Fig. 3). Wedge-type speculums placed between the cheek teeth tend to be in the way when positioning the sensor and are not useful. Damaging the radiographic plate is not a problem with cassettes containing film or CR screens, as these are very durable and a well-sedated horse will not damage them with their teeth. Smaller flexible intraoral sleeves designed to hold film and rare-earth screens or CR screens have been used for incisor and rostral dental radiography.\textsuperscript{5} These can be damaged if chewed but do allow for more caudal positioning inside the mouth. The DR systems with more fragile and expensive sensor plates can present more of a concern. If the sensor is in a hard, protective cover, then only a cloth to keep the cover from getting scratched or soiled is all the protection that is needed. A sheet of durable plastic used as a pliable kitchen cutting board can be fashioned as a cassette protector\textsuperscript{6}. These thin sheets of plastic can be cut to size and secured to the front and back of the sensor when needed with small Velcro sticky back fasteners\textsuperscript{6}. For systems without protection, the use of an aluminum speculum\textsuperscript{6} or special radiopaque carbon fiber incisor plates\textsuperscript{6} will be required.

Radiographs can be taken through these radiopaque incisor plates, but a slight shadow will appear on the radiograph (Fig. 4).

Radiographs should be taken with a right/left marker on the cassette/sensor indicating the sensor placement. Most digital systems have the ability to mark the radiograph at the time it is taken. These markups do not always stay with the radiographs especially if it is transferred as a jpg image; therefore, a lead marker should be used. The American Veterinary Radiology labeling convention should be used to label radiographs for easy sharing and consultation.\textsuperscript{9} The American Veterinary Dental College has adapted “labial mounting” for viewing dental radiographs. Images of teeth from the horse's left side are mounted on the right side of the radiograph and vice versa. The crowns of the maxillary teeth are pointed down and crowns of mandibular teeth are pointed up as if you were viewing them from the front of the horse.

To radiograph the upper incisors and canine teeth, the horse is sedated and positioned with the head steadied on a stand or stool and mouth relaxed. The cassette is placed in the mouth facing dorsal and pushed back as far as possible. The machine is positioned from dorsal to ventral by using a bisecting angle technique.\textsuperscript{6} Because of the changing angle of the incisor teeth with age, this requires about a 45° angle from horizontal in the young horse and an 70–80° angle to the plate in an old horse. It may be difficult to impossible to get the entire upper canine reserve crown and root in this view. There will be super imposition of the reserve crowns of the corner incisor teeth. Right and left 10–15° lateral oblique projections will bring these teeth in view (Fig. 5). To best view the upper canines, the cassette is placed as far caudal in the mouth as possible with the machine on the same side as the tooth in question. The machine is directed dorsal-ventral
at about a 45° angle to the plate and oblique at a 15–25° angle laterally. To complete the upper series of views, extraoral projections are required. A lateral open mouth view centered over the incisor roots can be helpful in evaluating fractures and other conditions in the area (Fig. 6). A radiopaque block can be used to open the mouth and raise the incisors off of the head stand (Fig. 7). To evaluate the upper canine teeth by using an extraoral technique, the plate is positioned on the side of the head and centered over the teeth to be radiographed. The beam is directed in a 10–15° caudo-rostral oblique angle. In most cases, both upper canines can be seen on a single view.

To radiographically view the lower incisors and canines, an intraoral technique similar to the uppers is used with the plate turned over facing ventral and the machine facing in a ventral-dorsal direction. The same technique and angles used for the upper incisors is required (Fig. 8). Because of the close proximity of the corner incisors and the lower canines, extraoral projections are needed. The narrow width between the lower jaws makes it impossible on some horses to get both lower canine teeth in the same view, and a right and left series is required.

3. Results and Discussion

Often, incisor and canine disease is missed when equine practitioners perform routine dental care. Any dental crown abnormality detected on an oral examination is an indicator that the tooth is diseased. Only the exposed crown of the tooth and surrounding gingiva can be directly evaluated from the oral cavity. Diagnostic quality radiographs of the incisor and canine teeth can add to the clinician’s ability to diagnose and treat various forms of dental disease affecting these teeth. Radiographs can be obtained in the standing sedated horse with equipment that is readily available to the equine practitioner. Heavy sedation and restraint using a headstand adds to the ease of the procedure and minimizes radiograph retakes. Utilization of this
described technique will improve the quality of dental care you can provide to your equine patients.

Since the early part of this century, with the introduction of DR and increased use of radiography in the field, several new dental disease processes have been diagnosed and studied. The most discussed of these is EOTRH. Researchers and clinicians have gained a greater understanding of the incidence, pathogenesis, and severity of endodontic disease, periodontal disease, dental tumors, developmental dental conditions, and several types of dental malocclusions. We no longer can afford, as a profession aimed at the “good of the horse,” to ignore dental disease until it is in an advanced stage, the horse has suffered for an extended time, and extraction is the only treatment option. Radiography along with oral endoscopy and three-dimensional imaging (CT and MRI) are more readily available. These tools and techniques have advanced dental care to a new level for the benefit and overall good health of the horse.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes


aDormosadan, Zoetis Inc., Kalamazoo, MI 49007.
Silicone Cutting Boards, Casabella Inc., Congers, NY 10920.
\(^{c}\)Velcro Brand sticky back fasteners, squares 7/8 x 7/8, Velcro, United Kingdom.
\(^{d}\)AlumiSpec, Veterinary Dental Products LLC, Elmwood, WI 54740.
\(^{e}\)XTandR biteplates, Podoblock USA, Hobe Sound, FL 33455.
\(^{f}\)Dental X-Block, Podoblock USA, Hobe Sound, FL 33455.
How to Radiograph Cheek Teeth

Leah Limone, DVM

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1. Introduction

Our ability to diagnose dental disease in the horse has been significantly improved with the availability of digital radiography. Diagnostic images are readily obtained with portable computed or direct digital radiography units, and practitioners are able to either proceed with treatment in the field or plan for later procedures. Many practitioners find difficulty in obtaining radiographs of the horse’s skull that are of diagnostic quality. Appropriate positioning of the x-ray sensor and x-ray machine are necessary to obtain diagnostic images. The descriptions offered here can help the practitioner improve their skills in dental radiography, which will then improve recognition of radiographic signs of dental and paradental pathology. As most equine practitioners do not have access to intraoral phosphor plates, extraoral techniques for evaluating the cheek teeth are presented. Additional techniques to improve diagnostic quality were reviewed in the 2016 AAEP Proceedings. Bilateral images (of both normal and abnormal arcades) are necessary for reliable radiographic interpretation. Proper labeling of the radiographs is essential for accurate interpretation. The American Veterinary Dental College convention of presenting the radiographs with “labial mounting” is used in conjunction with the American College of Veterinary Radiology terminology. Radiographs are presented so the viewer is looking at the images as if looking into the horse’s mouth. The right cheek teeth would be presented with the horse’s nose on the viewer’s right. The dorsoventral (DV) views of the skull are presented with the nose down, and the horse’s left side on the viewer’s left.

2. Materials and Methods

Dental radiography is facilitated by adequate sedation, an assistant, and the use of a speculum to open the mouth for most views. Open mouth lateral oblique views allow for optimal image quality, as the superimposition of contralateral cheek tooth rows is reduced or eliminated. The author’s preferred sedation protocol is intravenous administration of detomidine (0.01–0.02 mg/kg) used in combination with butorphanol (0.005–0.01 mg/kg). Appropriate sedation lowers the horse’s head, which can then be rested on a low support, such as a stool or headstand. Resting the radiographic sensor on the same object greatly diminishes motion artifact.

Bilateral images (of both normal and abnormal arcades) are necessary for reliable radiographic interpretation. Proper labeling of the radiographs is essential for accurate interpretation. The American Veterinary Dental College convention of presenting the radiographs with “labial mounting” is used in conjunction with the American College of Veterinary Radiology terminology. Radiographs are presented so the viewer is looking at the images as if looking into the horse’s mouth. The right cheek teeth would be presented with the horse’s nose on the viewer’s right. The dorsoventral (DV) views of the skull are presented with the nose down, and the horse’s left side on the viewer’s
right. As the sensor and generator are hand-held, adequate protective gowns, gloves, and a thyroid shield are necessary. The practitioner should ensure that the assistant is never in the primary x-ray beam.

To image the maxillary and mandibular premolars and molars, extraoral oblique projections are most informative. These are open-mouth views, with the sensor held flush with the lateral aspect of the horse’s head next to the target cheek tooth row, the same as if a straight lateral view were being taken. The straight lateral projection is primarily used for assessment of the paranasal sinuses, and it provides little useful information with regard to the teeth, as the apices of the left and right cheek teeth are superimposed.

Maxillary Cheek Teeth Apices
Figure 1A shows the right dorsal to left ventral lateral oblique view of the maxillary cheek teeth (Rt30D-LeVO). The author uses a modified Stubbs speculum to obtain open mouth extra-oral images. As shown in Fig. 1B, the sensor is on the affected side of the horse’s head, and the x-ray generator is raised 30–45 degrees from the straight lateral position and the beam centered on the rostral end of the facial crest. A slight (5–10 degree) caudo-rostral angulation allows better imaging of the interproximal spaces between cheek teeth and avoids rostro-caudal superimposition of cheek teeth within the same row. Opening the mouth for this view decreases the superimposition of the mandibular cheek teeth. This view separates the left and right maxillary cheek teeth rows to allow evaluation of individual apices. The buccal roots of the left maxillary cheek teeth are separated from the palatal root, allowing clearer assessment of the mesial and distal buccal roots. With the exception of the maxillary 2nd premolars,
the palatal roots are generally not isolated in this view.

Maxillary Cheek Teeth Palatal Root and Mandibular Cheek Teeth Apices

Figure 2A displays the right ventral to left dorsal lateral oblique view of the maxillary cheek teeth (Rt45V-LeDO). Figure 2B shows the sensor is on the left side of the horse’s head, and the x-ray generator is lowered 45–60 degrees from the straight lateral position and the beam centered approximately 1-inch ventral to the rostral end of the facial crest. This positioning isolates the apices of the left maxillary cheek teeth, projecting the palatal root dorsal to the buccal roots. A steeper angle (60-degrees or more) is needed in the young horse (with longer reserve crowns).

In Fig. 3A, the right ventral to left dorsal lateral oblique view (Rt45V-LeDO) of the left mandibular cheek teeth is shown. The apices of the left mandibular cheek teeth are imaged in this view. Figure 3B displays how the sensor is on the left side of the horse’s head, and the x-ray generator is lowered 45–60 degrees with the central beam directed at the center of the left mandibular arcade to image the left mandibular apices. This projection separates the left and right mandibular cheek teeth rows to allow evaluation of apices and the mandible. With an increased angle, greater distortion of the apices occurs, but may be necessary to separate the rows in smaller heads. Imaging of the caudal mandibular cheek teeth may require increased exposure and direction of the beam further caudally due to the thick masseter muscle.

Clinical Crown Projections

The clinical crowns are typically not assessed on conventional views due to superimposition of the opposing arcade. A reduced angle and opposite direction of the beam allows for imaging of the clinical crowns to evaluate crown fractures, diastemata, and horizontal and vertical bone loss secondary to periodontitis. To image the maxillary crowns, the beam is directed 10–15° ventrolateral to dorsolateral. To image the mandibular crowns, the beam is directed 10–15° dorsolateral to ventrolateral.

Figure 4 displays the right dorsal to left ventral lateral oblique view of the left mandibular cheek teeth (Rt10D-LeVO). This positioning is similar to that used for Fig. 1 but with less angle (10°) and with the central beam directed at a more ventral location but still at the level of the rostral end of the facial crest. This view isolates the crowns of the left mandibular cheek teeth.

DV Radiographs

The straight DV view is also of benefit when imaging paranasal sinuses, and offset mandible DV views...
allow for separation of mandibular and maxillary arcades in the DV orientation.

Figure 5 displays the left (A) and right (B) offset mandible DV views are used to reduce the overlapping images of the maxillary and mandibular cheek teeth. Assistants can offset the mandibles with gauze bandage, or a commercially available speculum can be used (C). The sensor is held underneath and parallel to the mandibles, and the beam directed perpendicular to the plate centered at the rostral end of the facial crest on midline.

3. Discussion

The ability to take quality diagnostic dental radiographs in the field is a valuable tool in the diagnosis and management of dental disease. The radiographic appearance of cheek teeth and their apices vary significantly with age, and an appreciation of normal variations is required for accurate interpretation of dental radiographs. Practitioners are encouraged to image both left and right views for comparison of the “normal” side to the side of interest. Becoming adept with taking and reading dental radiographs will increase the level of service practitioners provide and thus improve the overall health care of their patients. It is important to understand the limitations of radiography to clearly diagnose dental disease in complicated cases. Additional advanced imaging with computed tomography, nuclear scintigraphy, or magnetic resonance imaging may be required to better characterize the extent and exact location of disease involving multiple teeth or sinus disease. Proficiency with the standard radiographic views of equine cheek teeth as described here will allow the practitioner to obtain diagnostic images for immediate use in the field or for consultation.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes


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How to Diagnose Periodontal Disease

Matt Evans, DVM

1. Introduction

Periodontal disease (PD) is widely recognized as the leading cause of tooth loss in the equid. Multiple studies and reports discuss the prevalence of PD in several different equine populations as between 35%–85% and that 75% of cheek teeth (CT) extractions in private practice are secondary to PD.1–4

Despite the recognition of the ubiquitous nature and clinical significance of PD, there is very little literature addressing the diagnosis of PD using evidence-based medicine in the horse. Furthermore, there is also no literature available describing the different types of PD seen in the equid or looking into how different presentations of PD in different anatomic locations might influence clinical decisions.5

The main body of work on equine PD focuses on the diagnosis and treatment of PD, secondary to pathologic diastema.6,7 Guidance on cases that do not fit the diastemata diagnosis and debridement model or criteria leave the practitioner looking to diagnostic and treatment plans for equine PD based on extrapolation of human and small animal data and expert opinion.8,9

This paper summarizes the current standards for examining and quantifying PD in the horse. Due to time constraints and previous literature already covering incisor and canine PD thoroughly, this paper and presentation focuses on PD of the CT.

2. Materials and Methods

- sedatives (detomidine and butorphanol)
- head stand or dental halter
- dental speculum
- head lamp or other oral light source
- dental mirror or oral endoscope (Fig. 1)
- periodontal probe (Fig. 2)
- alligator forceps (Fig. 3)
- local anesthesia (mepivacaine and butterfly catheters)
- radiographic machine
- dental chart

Equine PD can be suspected based on anamnesis; common historical findings associated with PD are quidding, weight loss, and halitosis.5–7 PD may also be noted on routine physical exam if there is facial swelling, draining tracts, or sinusitis, but these would only be present in chronic and severe cases.

The key to diagnosing and quantifying equine PD is a thorough oral examination.10,11 This begins with a well-sedated patient. The author uses intravenous 0.02 mg/kg detomidine and 0.006 mg/kg butorphanol as the base sedation for a routine oral exam. This dose might need to be increased in patients where PD is found, as the cleaning and examination of equine PD is painful for the patient.12

A full mouth dental speculum is necessary for a complete oral exam, as is some method of rinsing the
mouth clean. A high-quality head lamp or speculum light is a must to facilitate the complete oral exam. Anywhere that feed or organic debris is collected must be fully cleaned; this can be achieved with a water source or hand tools.\(^\text{10,11}\)

Once the mouth is open and clean, the entire oral cavity is examined using a mirror or endoscope. This includes every surface of and the periodontia of each tooth. Areas with continued food packing, gingival hyperplasia, gingival recession, and gingival inflammation are noted for further examination.\(^\text{9,10}\) (Fig. 4)

If an area of concern is identified, it is completely cleaned of organic debris and the mirror or endoscope, along with the periodontal probe, are used to quantify the extent of the periodontal lesion as closely as possible. This is, again, often painful for the patient and local anesthesia distal (caudal) to the area in question can be used to facilitate ease of cleaning and examination, if the patient is reactive.\(^\text{13}\) The author places local anesthesia in the palatal ridges or the buccal/lingual gingival reflection by using a 23-ga butterfly catheter attached to a 3-mL syringe and by placing 20 mg of mepivacaine in two to three locations, again, distal to the lesion.\(^\text{14}\)
The lesion is quantified by naming the exact location of the lesion within the Triadan numbering system on the dental chart and then measuring the size of the periodontal lesion in all three planes (i.e., PD between teeth 109 and 110 on the palatal aspect that is 1 cm mesial to distal, 1.5 cm palatal to buccal, and 1 cm deep). The depth of a periodontal lesion is measured using the periodontal probe and compared with the normal gingival depth of surrounding teeth, which might have to be visually estimated, as it may be several centimeters away. Also, the tooth in question should be carefully inspected for fractures or necrotic pulps that would be indicative of a larger problem that may be both endodontic and periodontic in nature.10,11 (Fig. 5).

Also useful in describing PD are the Tooth Mobility Index and Gingival Index15,16 (Tables 1 and 2). Once the lesion is located and noted on the dental chart, the next step is attempting to identify if there is a class one malocclusion tooth or teeth either causing or secondary to the lesion. A class one malocclusion is defined as any deviation from normal occlusion.17 An example of class one malocclusions that can be causative are teeth that are rotated or tilted in their socket that allow food packing between two teeth. Examples of class one malocclusions that are likely secondary to the periodontal lesion are overlong teeth and abnormal transverse ridges. Most often, though, it is very difficult to discern if the class one malocclusion came before or after the PD, but the important point here is to assess the occlusion of the patient looking for a class one malocclusion.

The next step in quantifying PD is the Periodontal Disease Index15 (Table 3). Accurate use of this chart requires radiography to assess the degree of bone loss. How to decide when an equine tooth with PD is severe enough that radiographs are indicated is not something that is well described in the literature. The normal periodontal probe depth in the horse is described as 5 mm,18 but this does not take into account the measurements in the other two planes of reference. The author uses a combination of Gingival Index, Tooth Mobility Index, and then the measured size of the lesion, coupled with clinical signs and presenting complaints, to decide how aggressively to recommend radiography. For lesions that those indices are severe, radiographs are aggressively recommended. Frequently, in the asymptomatic horse with low scores and a smaller or newly identified lesion, the author will recommend performing odontoplasty to address any class one malocclusions found and then reassessing the patient at a shorter interval (three to six months, depending on the case).

If radiographs are obtained, they are done so by using the described standards in equine dental cases.19,20 The radiographs are evaluated for degree of bone loss, both vertical and horizontal, to

![Fig. 5. Pulp exposure of pulp number 5 of a 209 with associated complicated crown fracture and PD.](image)

**Table 1. Tooth Mobility Index**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Degree of Mobility</th>
</tr>
</thead>
<tbody>
<tr>
<td>M10</td>
<td>Mild normal.</td>
</tr>
<tr>
<td>M11</td>
<td>Represents the first distinguishable sign of movement greater than normal.</td>
</tr>
<tr>
<td>M12</td>
<td>Moderate movement of up to approximately 3 mm.</td>
</tr>
<tr>
<td>M13</td>
<td>Severe movement &gt;3 mm in any direction and/or is depressible.</td>
</tr>
</tbody>
</table>

MI, mobility index.

**Table 2. Gingival Index**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Examination Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>GI0</td>
<td>Normal gingiva.</td>
</tr>
<tr>
<td>GI1</td>
<td>Mild inflammation, slight color changes, slight edema; no bleeding on probing.</td>
</tr>
<tr>
<td>GI2</td>
<td>Moderate inflammation; redness, edema, and glazing; bleeding on probing.</td>
</tr>
<tr>
<td>GI3</td>
<td>Severe edema.</td>
</tr>
</tbody>
</table>

GI, gingival index.

**Table 3. Periodontal Disease Index**

<table>
<thead>
<tr>
<th>Stage</th>
<th>Degree of Attachment Loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>PD0</td>
<td>Normal.</td>
</tr>
<tr>
<td>PD1</td>
<td>Gingivitis; no bone loss; probing depth &lt;5 mm.</td>
</tr>
<tr>
<td>PD2</td>
<td>Early PD; &lt;25% attachment loss.</td>
</tr>
<tr>
<td>PD3</td>
<td>Moderate PD; 25%–50% attachment loss.</td>
</tr>
<tr>
<td>PD4</td>
<td>Advanced PD; &gt;50% attachment loss.</td>
</tr>
</tbody>
</table>

PD, periodontal disease.
place the tooth or teeth on the Periodontal Disease Index. The tooth is also evaluated for signs of periapical disease that could either be primary, usually concomitant with an endodontic lesion, or secondary to severe PD\textsuperscript{21} (Fig. 6).

3. Results and Discussion

Given the importance of equine PD and the lack of significant evidence-based literature on how to diagnose and treat PD, the author believes that using the above multidimensional method to identify, quantify, and record PD is currently the best care for patients in equine dentistry. Treatment of PD in the horse is beyond the scope of this “how-to” paper, but is a topic that, along with an accurate diagnosis of PD, will advance and new papers should be watched for in the future.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

References


Fig. 6. Radiograph of a 309 with both horizontal and vertical bone loss causing PD\textsuperscript{4}.
How to Use Rotary Burs in Equine Dentistry

Molly K. Rice, DVM

1. Introduction
As the practice of equine dentistry has advanced in the last 15–20 years, so has the development of instrumentation and techniques that aid management of equine dental disease. This manuscript discusses the use of rotary burs to aid extraction of diseased cheek teeth, including partial coronectomy and tooth sectioning techniques. Partial coronectomy\(^1,2\) has been described as a technique that involves the partial removal of the clinical crown of the diseased tooth to the level of the crestal bone in a manner that eliminates crown interlock. The creation of this 3–4-mm space facilitates loosening of the tooth by allowing less pressure to be applied to the clinical crown with spreaders and luxators. Tooth sectioning\(^2,3\) can facilitate extraction of teeth with minimal clinical crown or root abnormalities such as dilacerations or malformations. Both of these techniques can provide alternatives to more invasive techniques such as tooth repulsion and invasive lateral buccotomy that may carry a higher complication rate.\(^4–6\)

2. Instrumentation
There is a wide variety of instrumentation available for odontoplasty,\(^7\) some of which come with options for use of rotary burs. Rotary burs can include a variety of diastema widening burs and double cut carbide (tile cutting-type) burs. In the author’s practice, the primary instrument used in partial coronectomy and tooth sectioning is the Versa-Float\textsuperscript{Tm} with NSK 300 head fitted with a 3 × 52-mm double cut carbide bur\(^5\) (Fig. 1). The VersaFloat has water irrigation, which may reduce the risk of thermal injury\(^8–11\) and improves visibility by reducing dust production. There are extended length burs available in 57- and 76-mm lengths\(^a\) (Fig. 1). Some of the extended length burs come with shorter flutes (Fig. 1), which allows a more precise cutting surface at greater depth. There are likely other instruments that could be adapted for partial coronectomy and tooth sectioning, but the author has limited knowledge of these.

3. Indications for Use of Rotary Burs in Exodontia
The partial coronectomy technique can be potentially beneficial in nearly all cheek tooth extractions due to the reduction in crown interlock, which facilitates more rapid loosening of the tooth. This is particularly beneficial in teeth in the middle of the dental quadrant (Triadan 08–10s). Cheek teeth with nonvital pulp exposure, advanced infundibular caries, or crown fractures benefit from partial crown removal because this allows spreaders or luxators to be applied to the tooth with minimal pressure on the diseased/fragile clinical crown.\(^1–3\)

Teeth that benefit from tooth sectioning may have fractured or diseased clinical crown, dilacerated...
roots, root malformation, or dysplasia that may affect normal delivery of the tooth in one piece.

4. Preparation of the Patient

- The horse is sedated and restrained in a standing stockade. Oral examination and appropriate diagnostics are made to formulate a treatment plan. Careful planning of the extraction process should always include adequate time allotment for the procedure to minimize stress on the operator. Appropriate regional anesthesia\textsuperscript{12–17} is necessary to facilitate patient compliance during tooth sectioning and partial coronectomy procedures.
- Traditional extraction methods\textsuperscript{18} are used to initiate the extraction process, including sulcular incision, gingival elevation, molar spreading, and use of extended luxators\textsuperscript{a} (Fig. 5B).
- Transition to partial coronectomy or tooth sectioning occurs when pressure applied to the clinical crown is likely to induce potential fracture or crumbling of the clinical crown. In teeth with fractured clinical crowns, or extensive tooth decay, this transition may be made early in the extraction process, often before spreaders are applied to the tooth.

5. Partial Crown Removal

- Crown removal is achieved with a water-irrigated double-cut carbide bur on the VersaFloat\textsuperscript{1,2} (Fig. 2). Frequent visualization with an oroscope or intraoral dental mirror is very important to confirm that the cut is being made in the appropriate plane (Fig. 3).
- Care must be taken to align the cut with the long axis of the tooth being removed (Fig. 3C). Unlike diastema widening,\textsuperscript{19–21} which will remove portions of clinical crown from two adjacent teeth, partial coronectomy will only remove crown from the tooth being extracted.
- It is imperative to only remove 3–4 mm of the clinical crown in a coronal plane, as making too “wide” a cut will potentially further weaken the clinical crown and possibly impair extraction efforts by making the clinical crown more difficult to grasp with forceps.

The depth of the cut is dictated by the age of the horse and the location of the crestal bone (Fig. 3E), which is identified on preoperative and intraoperative radiographs.

- Frequent intraoperative radiographs are recommended to guide the cutting process, especially when learning the technique. A common mistake is to hold the handle of the cutting instrument too low (for maxillary cheek teeth) or too high (for mandibular teeth), causing the cutting bur to be directed in a rostral direction (Fig. 4). Failure to identify improper cut alignment can contribute to crown failure due to excessive removal of tooth material.
- The clinical crown should be removed to the level of crestal bone to eliminate crown interlock. It is very important that a complete cut is made and demonstrated on radiographs prior to placing molar spreaders. An incomplete cut may leave dental material that could cause crown interlock, resulting in fracture of the clinical crown when spreading forces are applied to the tooth. If fairly rapid loosening of the tooth does not occur, re-evaluate for completeness of cut, both in depth and the medial to lateral aspects of the crown removal.
- In most cases, starting with a distal interproximal cut is recommended, as this best
facilitates spreading and delivery of the tooth along the pathway of eruption in most cases. Each tooth must be individually evaluated based on the disease present, as this may influence whether a mesial or distal cut is made. For example, in a tooth with a complicated crown fracture through pulp horns 3 and 5, it may make more sense to start with a mesial interproximal cut because there is a portion of crown missing there already. In cases where there is not a compelling reason to cut the mesial aspect first, a distal cut is usually the best option for most teeth.

- Once the completed interproximal cut has been made and confirmed on radiographs, molar spreaders or extended luxators can often be applied to the opposite interproximal space (Figs. 3F and 5), to facilitate tooth loosening in a mesial to distal direction. The tooth should loosen fairly quickly with minimal pressure placed on it if the cut was properly made. In the event that this does not occur, the cut should be evaluated to see if extending it deeper might help provide more room for tooth movement. If that does not help, then making a cut on the other interproximal border (mesial or distal) may be indicated to facilitate further loosening of the tooth (Fig. 6). Care must be taken when performing two interproximal cuts, as this will significantly reduce the amount of clinical crown left for molar forceps placement.

- Once sufficient mobility of the tooth has been obtained through the use of molar spreaders and luxation forceps, the tooth may be gently grasped with molar forceps for further manipulation. In teeth with minimal decay, molar forceps can be used earlier in the process, as the tooth is less likely to crumble or fracture. In severely decayed or fractured teeth, it is wise to not place molar forceps until sufficient mobility has been attained such that delivery of the tooth is imminent. This will reduce the chance of clinical crown fracture and contribute to a higher success of intraoral tooth extraction.
6. Tooth Sectioning

- Crown removal is achieved with a water-irrigated double-cut carbide bur on the Versafloat.²,³
- Tooth sectioning differs from partial coronectomy in that tooth length plays a major role in patient selection. Because the cut needs to extend through the entire length of the clinical and reserve crown, it is important to determine that the appropriate length of bur is available to successfully perform the cut. In young horses, this may mean that tooth sectioning is not possible and should not be attempted.
- Mandibular teeth are sectioned between pulp horns 1 and 2 in a lingual to buccal direction, to the level of the furcation (Fig. 7). The process is guided by intraoral radiography to properly align the cut. Improper alignment can lead to transection of the root, which can severely complicate extraction efforts!
- Maxillary teeth are sectioned in a mesial to distal direction, through the plane of the infundibula, separating the palatal root from the two buccal roots (Fig. 8A). Due to the plane of this cut, intraoperative radiography is not helpful in guiding this process. Care must be taken to not perforate the apical bone, particularly on the maxillary 08–11s, to avoid penetration into the paranasal sinuses.
- Maxillary teeth can have an additional sectioning cut made to separate the mesial and distal buccal roots if needed (Fig. 8B). This cut is made after the cut through the infundibula is completed.
- A completed sectioning cut can be determined in mandibular teeth by radiographs. Visual inspection of the cut is often difficult due to blood pooling in the apical margin of the cut. When the cut is being made in maxillary cheek teeth, there will be bleeding noted at the apical margin of the cut when the tooth has been sectioned all the way through. Application of luxators to provide lateral distraction of the fragments should reveal independent movement of the tooth when properly sectioned.
- Once the tooth has been completely sectioned, luxation forceps and sometimes molar spreaders are used to promote tooth mobility.
Fig. 7. Intraoperative radiography of a 306 tooth sectioning. A–C, Yellow arrows depict alignment of the cut between pulp horns 1 and 2. C, The red arrow demonstrates proper alignment of the cut with the root furcation. D, The cut is completed to the furcation (red arrow). E, Postextraction radiograph. F, The extracted tooth.

Fig. 8. Two examples of maxillary tooth sectioning. A, This tooth has been sectioned in the plane of the infundibula (yellow arrows), separating the buccal two roots from the palatal root. B, This tooth has been sectioned through the infundibula (yellow arrows), in addition to a second cut (red arrows) that has separated the mesial and distal buccal roots.
ment forceps are then used to deliver the tooth sections individually.

7. Discussion

The techniques described here are useful for augmenting good intraoral extraction technique. Although they are most helpful for extraction of decayed or fractured teeth, they can also be useful for extracting nondecayed teeth with apical infections by potentially reducing surgery time and minimizing trauma and stress placed on adjacent cheek teeth. Tooth sectioning can be performed in conjunction with partial coronoectomy or as a separate technique. It is most commonly performed in mandibular teeth but can be useful for extraction of maxillary teeth as well. Sectioning of maxillary teeth is particularly helpful in older horses, as they sometimes have dilaceration or enlargement of the palatal root that inhibits delivery of the tooth with extraction forceps.

These techniques can be technically challenging to learn, and practice with cadaver specimens is recommended to gain experience prior to use in clinical patients. Keys to success include adequate sedation for the patient and appropriate regional nerve blocks, which minimize tongue or head movement that can be detrimental to the success of the procedure. Frequent intraoral examination with an oroscope or mirror, combined with intraoperative radiography is also vital to guiding the successful completion of crown removal techniques. With practice, good success rates of intraoral extraction can be achieved.1

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes


*aVersaFloat, Veterinary Dental Products, LLC, Elmwood, WI 54740.
*bRoto-Zip Tilecut Bit, Chicago, IL.
How to Manage the Geriatric Dental Case

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1. Introduction
The equine hypsodont teeth are continuously erupting, and, therefore, the oral cavity is continuously adapting to this change. However, the long crowns are also of fixed length and do eventually expire later in the horse’s life. In fact, dental disease has been reported in 88% of equids over 20 years in age. Therefore, there are several considerations when performing dental examination and treatment on the geriatric horse. As dental enamel expires at the end of the life of a tooth, that equates to loss of a suitable grinding occlusal surface on a cheek tooth. Asymmetrical expiration of enamel across the surface of a tooth or on opposing teeth can lead to painful mucosal ulceration associated with dental overgrowths. Additionally, periodontal structures surrounding expiring teeth adapt significantly in response to the forces of mastication and the environment surrounding the tooth as the horse ages. The density of the collagen fibers along with the bundles of collagen fibers both increase with age in the periodontal ligament. These structural changes within the periodontium occur to support the tooth as the reserve crown length decreases over time, although the process still leads to eventual shedding of the tooth.

Beyond dental overgrowths and malocclusion, however, there are several clinical conditions and special considerations to bear in mind when dealing with a geriatric horse. Unrelated clinical conditions, such as degenerative joint disease (DJD) or pituitary pars intermedia dysfunction (PPID), may affect the dental examination or contribute to dental disease and should be considered before entering into dental treatment. Additionally, there are several conditions, such as senile diastemata leading to severe periodontal disease or equine odontoclastic tooth resorption and hypercementosis (EOTRH), that disproportionately affect aged horses.

The goal with all dental treatment, but particularly in geriatric horses, should be to maintain normal chewing and comfort while preserving as much of the remaining tooth as possible and keeping the mouth free of any pain and inflammation through early detection. Through preserving oral health, the objective is to provide horses with adequate dentition to masticate enough for age to supply their nutritional demands (typically at least 1.5% body weight/day) or to supplement the horse’s nutrition if the dentition can no longer support this consumption. Although in the past, a horse’s lifespan may have been dictated by their dental attrition and eventual total wear of the dentition, this is no longer the case, as proper dental maintenance coupled with proper modern nutrition can support a horse long past the life of its teeth.
2. Examination and Evaluation

Clinical Examination Prior to Dental Evaluation
A thorough physical examination is necessary prior to any dental evaluation but particularly important to discover underlying health issues in geriatric horses. Poor body condition may be a sign prior to a dental exam that a horse is unable to meet its nutritional requirements but may also be a sign of underlying systemic pathology. Any sign of lameness, DJD, or laminitis should be considered, as these patients may have difficulty standing for prolonged procedures or maintaining their balance when sedated. Particular attention should be paid to any sign of PPID or metabolic disease, as delayed healing and increased rates of complications following dental procedures have been noted in these cases. Cardiac auscultation may reveal a murmur that may be a minor age-related change to a valve but could be a significant indication of developing cardiac failure or decompensation. If any significant abnormalities are noted during physical examination of a geriatric patient, appropriate diagnostics (axial limb radiography, hematology, echocardiography) along with treatment or control of any significant pathology is recommended prior to commencing dental treatment if possible. However, dental treatment is sometimes necessary concurrent to treatment of systemic pathology and must be evaluated on an individual case basis.

Complete and Thorough Dental Evaluation
Sedation in geriatric horses may be a challenge, as an aged horse may be less steady on its feet or may be affected by a cardiac condition of concern. However, sedation is necessary in nearly all patients to avoid undue stress, perform a thorough examination that can identify even subtle pathology, and provide some analgesic effects, as many dental conditions found in aged horses can be very painful. Romifidine (0.4 mg/kg) coupled with butorphanol (0.025 mg/kg) administered intravenously often produces less ataxia than other sedatives and is often a good choice when treating potentially unsteady horses. However, the duration of action of romifidine is longer than that of other alpha2 agonists when the length of sedation is a concern, and the effect of romifidine is subjectively not as profound as the effects of other alpha2 agonists in the horse. Therefore, other alpha2 agonists should be considered when the length or discomfort of a procedure is of concern. Additionally, physical support such as stocks may assist the horse during prolonged procedures, although close attention must still be paid to ensure they remain steady on their feet.

Prior to opening the mouth, the incisors should be closely examined for any pathology but also to determine their stability. Incisors may be fully worn or may be unstable or prone to fracture due to peri-

odontal disease and EOTRH. If stability of the incisors is in question, radiographs should be obtained prior to placing the speculum. Caution should be taken if evidence of EOTRH is present, and pain should be anticipated if incisor instability is suspected. Additionally, the bite plates of the speculum can be padded using cotton or bandage materials to provide more comfort for the animal. Once the horse is sedated and the speculum is placed, a full mouth examination should be performed using a bright light source and dental mirror or oroscope.

3. Special Considerations in Pathology and Treatment

Malocclusion and Occlusal Wear Abnormalities
The use of a mirror or oroscope is essential to examine the occlusal surface of all cheek teeth for changes in the occlusal enamel, dentine, and cementum. The combined structure of the cementum, dentine, and the irregular pattern of enamel folds on the occlusal surface creates the self-sharpening mechanism of the equine cheek tooth; however, different components of the tooth wear at varying rates. Enamel wears most slowly, dentine wears most quickly, and the rate of cemental wear lies in between. Infundibula are present in both maxillary cheek teeth and incisors in the horse. They are comprised of an infolded enamel-lined cup opening onto the occlusal surface filled with cementum. Mandibular cheek teeth do not contain infundibula, but they do contain a greater degree of peripheral enamel infoldings than the maxillary teeth. Excessive wear in portions of or in an entire tooth occlusal surface is attributed to reduced enamel content or delayed eruption of that tooth, respectively, which then leads to the development of overgrowth in the opposing tooth (Fig. 1).

Enamel content of the cheek teeth is critical, as it is the most dense and most wear-resistant dental tissue and essential for grinding silica-containing food material, such as hay and grass. Enamel content is at its maximum when the permanent tooth first develops and erupts and only decreases over time as the tooth wears. Additionally, there is a decrease over time in the amount of functional enamel exposed on the occlusal surface, meaning that there is less of a surface area to be used for grinding food material as the horse ages. Enamel also is unable to regenerate or repair itself. Maxillary cheek teeth infundibula likely evolved to give a greater length of enamel folds on the occlusal surface to compensate for the more extensive enamel infolding present in the mandibular cheek teeth. However, the central infundibular enamel cups often end at least several millimeters more occlusal than the peripheral enamel folds. Therefore, the infundibular enamel in the maxillary cheek teeth often expires more quickly than the enamel folds in the mandibular cheek teeth or the peripheral enamel folds in the maxillary cheek teeth, lead-
ing to a “cupped” appearance in the maxillary teeth also known as “senile excavation” (Fig. 2). As the enamel folds and other dental tissues continue to wear from the remaining clinical crown in both the maxillary and mandibular cheek teeth, individual teeth may expire as the clinical crown wears but is unable to be replaced. Eventually, the mouth may gain a “smooth” appearance, as the enamel is absent from all clinical crowns with only cemental root remnants remaining visible in the oral cavity (Fig. 3). Overall, the equine tooth erupts and wears at a rate of about 2–3 mm per year; therefore, equine dentition often expires when an equid is between 20–30 years in age, but this varies significantly between species, breeds, and individuals.

Treatment of the occlusal surface, including overgrowths and sharp enamel areas, should be restrained to those causing soft tissue injury or restricting normal masticatory movements of the jaw. Any dental tissue removed from the surface essentially decreases the life of the tooth and particularly needs to be restricted when the tooth begins to expire.

Infundibular Disease
Examination of the maxillary cheek teeth occlusal surfaces also allows for examination of the infundibula, specifically for development of significant caries lesions. Caries is a disease of the calcified tissues of the teeth whereby the interaction of bacteria and biological substrates, such as dietary carbohydrates, on dental tissues leads to the demineralization of the calcified dental tissues and destruction of their organic components. Infundibular caries in the horse is recognized as the progressive demineralization of dental cementum that may then extend to enamel and eventually the dentine, which can be seen on the occlusal surface of the tooth on dental examination. More severe caries also likely has some relation to infundibular cemental hypoplasia, which occurs when the cementum does not fully form in the infundibulum during development. This allows food to impact much more deeply into the infundibulum at an early stage and allows caries to progress much more quickly. Caries is frequently classified using the modified Honma scale, with Grade 0 being an unaffected “normal” tooth, Grade 1 caries affecting only cementum, Grade 2 caries affecting cementum and extending into the enamel, while Grade 3 caries progresses to involve the surrounding dentine layer, along with cementum and enamel (Fig. 4). Infundibular caries can progress and allow coalescence of both infundibula into one large carious central defect in the tooth (Grade 4), which can in turn degrade further and allow the impaction of food and debris into the tooth.
Infundibular caries weakens the structural integrity of the tooth, particularly when the infundibula begin to coalesce. Coalescing infundibular caries can lead to midline sagittal fracture and apical infection of the tooth, both of which necessitate extraction and may lead to further complications, such as secondary sinusitis. Any teeth with infundibular caries should be monitored on an annual or biannual basis. However, many cheek teeth with severe infundibular caries never fracture. Particularly as the horse ages, it is proposed that the crown length shortens and the tooth becomes more embedded in and supported by maxillary bone as opposed to protruding into the open sinus compartments and, therefore, may be less apt to fracture. If the structural stability or severity of the caries is in question, radiographs of the maxillary cheek teeth will assist in monitoring progression and treatment planning.

In an attempt to prevent the progression of infundibular caries and to improve the mechanical strength of affected teeth to prevent fracture formation and/or apical infection, restoration of carious infundibula has been described using dental drills and composite dental materials. It is a relatively subjective decision if and when to treat infundibular caries, as controlled case studies with long-term follow-up have yet to be published, but the procedure is performed by many advanced equine dental practitioners with reported success. There are no clear guidelines, but potential candidates may be infundibula with Grade 3 or severe Grade 2 infundibular caries and/or horses affected by midline sagittal fracture of the contralateral tooth and caries in the tooth in question particularly if horses are under 20 years in age or with teeth over 20 mm in crown length (Fig. 5).22,23

Diastemata and Periodontal Disease in Cheek Teeth

The use of a mirror or oroscope is also essential to examine the palatal/lingual and buccal gingival margins along the clinical crowns and the gingiva at all interproximal spaces between the cheek teeth for signs of diastemata and periodontal disease. The equine periodontium is comprised of four tissues, including the alveolar bone, the periodontal ligament, the gingiva, and the tooth’s peripheral cementum. The periodontal ligament provides a firm yet flexible attachment for the tooth to the body while also having reparative and regenerative properties,
along with facilitating the continued eruption of
the tooth throughout the life of the horse. Therefore, the equine periodontal ligament is very vascular and if damaged may be able to repair itself if managed properly. In geriatric horses, though, the inciting cause of much periodontal disease cannot be fully resolved. Teeth with severe periodontal ligament attachment loss or associated with unresolved painful diastemata may require extraction.

Periodontal disease is very common in aged horses and has been reported in 60% of horses over the age of 15 years. Most periodontal disease in equine cheek teeth is secondary to and associated with diastemata in the interproximal spaces. The senile diastemata most common in horses as they age are due to a combination of the tapering of the cheek teeth from occlusal to apical, along with the loss of compressive angulation of the cheek teeth (06 cheek tooth angles caudally/distally, 10 and 11 cheek teeth angle rostrally/mesially). Valve-shaped diastemata are often the most problematic, as they allow food to become entrapped at the gingival margin between cheek teeth but do not allow it to escape. This then begins a cycle of physical disruption of the gingival barrier, which allows bacteria and oral cavity contents to contact and begin to degrade the periodontal ligament itself. Continued stasis of food in the diastemata and physical impaction of food into the ulcerated gingiva lead to a remarkably painful and progressive condition (Fig. 6).

A thorough oral examination (using a mirror/oroscope) at the gingival margin along both sides of each cheek tooth row will allow the identification of diastemata. Any diastemata should then be cleaned of any impacted food material by using high-pressure lavage, diastema forceps, and/or specialized, commercially available periodontal treatment units and then reassessed to determine if there has been compromise of the gingival barrier, along with visible ulceration. A periodontal probe may also be used to determine the depth of any pockets. Once diastemata and potential periodontal disease has

Fig. 5. Computed tomography scan images of the same teenaged gelding performed 6 months apart. In the image on the left, the horse was affected by midline sagittal fracture of the 209 cheek tooth and maxillary sinusitis (star), along with deep infundibular caries of the 109 cheek tooth (arrow). In the image on the right performed 6 months later, the fractured tooth had been extracted and the sinusitis resolved (star), and infundibular restoration had been performed on the 109 infundibulum, albeit with a small gas defect at its apical margin (arrow).

Fig. 6. Severe gingival recession and food impaction in mandibular cheek tooth diastema (left); evidence of painful bleeding and ulceration during debridement and lavage of impacted food material (right).
been identified, radiography will allow the remaining periodontal ligament attachment to be assessed in its entirety and allow the severity of disease to be categorized as the following:

- **PD0**: No periodontal ligament loss
- **PD1**: gingivitis, no attachment loss
- **PD2**: < 25% attachment loss
- **PD3**: < 50% attachment loss
- **PD4**: ≥ 50% attachment loss

As the periodontium has the aforementioned reparative properties, attempts at treatment are often warranted prior to extraction of the tooth unless there is significant attachment loss and instability or the remaining crown as visualized on radiographs is minimal. The mainstay of any treatment of diastemata is the removal of any necrotic food material and debris from the interproximal spaces and periodontal pockets by using a combination of pressurized gas, water, and abrasive powders. Once the debris is removed, prevention of reimpaction is key to allow the periodontal tissues and gingiva to heal. Addressing dental overgrowths and malocclusions may significantly improve the horse’s diastema. Additionally, application of either periocutic antibiotics (such as doxycycline gel or capsules) or vinyl polysiloxane application in the interproximal space may act as a temporary preventative of food impaction. More permanent bridges produced from acrylic material may be indicated if the diastemata are resistant to treatment attempts or appear to be at risk of creating an oromaxillary fistula if the surrounding teeth are extracted.

If an interproximal space continues to entrap food in spite of more conservative treatment, diastema widening with mechanical bur instrumentation may be indicated but should only be performed by an advanced practitioner due to the risk of pulpar exposure or thermal damage to the pulp horns, as they may only lie 1.3 mm from the interproximal space (Fig. 7). Frequent reexamination (every 4–6 months) is recommended to regularly assess the progression or improvement of periodontal disease and determine the need for further treatment or extraction.

**Equine Odontoclastic Tooth Resorption and Hypercementosis (EOTRH)**

EOTRH is a more recently recognized resorptive dental disease affecting the incisors and canines of older horses. The roots of the affected teeth begin to resorb, likely due to an inflammatory or an immune response, as occurs in similar disease processes in cats or humans. Concurrently, though, cementum is laid down around the resorbing roots, stabilizing the teeth temporarily (Fig. 8). As EOTRH progresses, the periodontal tissues surrounding the teeth may begin to recede, leading to some loss in stability of the teeth. Additionally,

![Fig. 7. Diastema treatment: placement of vinyl polysiloxane in a mandibular cheek tooth diastema (left); successfully widened diastema (right).](image)

![Fig. 8. Radiograph depicting clubbed tooth roots and cemental deposits around the roots of incisors and canines of a horse affected by EOTRH (orange arrows). Note marked resorption of canine to right (red arrow).](image)
inflammation noted as subgingival thickening around the alveoli and abscesses may form at the apices of the teeth and surrounding the reserve crowns. Eventually, the combination of resorption and periodontal disease will lead to instability of the tooth, fracture of the degrading crowns, and pain in the horse (Fig. 9).\textsuperscript{31,32} Often, signs of pain are subtle and only noticed by owners when prompted including the following:

- Disinterest in grazing, grain and pelleted feeds, or treats such as carrots and apples
- Returning to wait at the gate shortly after being turned out
- Picking up hay and forage with the lips only
- Purposely avoiding contact of the maxillary and mandibular incisors (may place tongue between teeth)
- Subtle changes in attitude and interaction

Radiographs are used if there is a clinical suspicion of EOTRH upon examination of the incisors. Serial radiographs often assist in monitoring progression and planning for extractions when necessary. Despite many marketed commercial and homeopathic remedies, the only recognized treatment for affected teeth is extraction when the teeth begin to become unstable or there is noticeable pain in the horses.\textsuperscript{33} Clinical impressions are that complete incisor (\(+/-\) canine) extractions performed while standing in one procedure are most immediately effective and least stressful on the horse, with consideration of the horse's ability to stand while sedated for a prolonged period.

Deep sedation combined with bilateral infraorbital and mental nerve blocks and infiltration of local anesthesia into the gingiva and interproximal spaces surrounding the incisors is essential. However, the horse may still react painfully due to chronic painful stimulation of the nerves associated with the affected teeth. The teeth and surrounding bone will often begin to crumble, as it is often severely degraded and spongy by the point that significant EOTRH is recognized. In addition to extraction of the teeth, bone must be removed to the point that it is solid again. Many clinicians recommend suturing of the gingiva following full-mouth incisor extractions to expedite healing, although the owner should be warned that dehiscence will often occur. Horses will almost immediately begin to show improvement and continue to do well long following extraction of all affected teeth despite occasional protrusion of the tongue. Other than struggling on very short pasture, horses can continue to eat and work normally, often surviving long after extractions occur.

4. Discussion

As horses continue to live longer just like their human counterparts, awareness of the particular challenges in geriatric dentistry is of utmost importance. A thorough physical examination prior to dental evaluation is essential to prevent potential complications whenever possible. A complete and thorough dental evaluation using appropriate sedation will then allow identification of developing problems before they become significant. If there is any doubt in the significance of a problem, frequent re-examination will assist in closely monitoring the issue and avoid embarking upon aggressive treatment unnecessarily. As geriatric horses have limited amounts of tooth remaining, more conservative treatments more frequently are typically appropriate to preserve as much of the crown as possible. The attending veterinarian must consider the overall health of the oral cavity but should have an understanding of the pathogenesis and treatment options for EOTRH, infundibular caries, and periodontal disease, along with the process of tooth expiration in the horse. If properly recognized and understood, dental disease in geriatric horses can be well managed, and horses may even long outlive their teeth.

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Fig. 9. Progressive tooth resorption, fracture, and loss in a case of severe EOTRH.


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

Conflict of Interest
The Author has no conflicts of interest.

References
At a Crossroads: Bureau of Land Management’s Wild Horse and Burro Program

Bruce H. Rittenhouse, BS, MS

Currently, the Bureau of Land Management’s (BLM) Wild Horse and Burro Program is at a crossroads as populations on the range are overpopulated, causing poor animal health and degradation of public rangelands. High holding costs for excess animals that have been removed from the range limit effective on-range management. The BLM has recently submitted a report to Congress that outlined four options and other administrative/legislative actions to improve the management of wild horses and burros on public lands and meet agency goals. Author’s address: Acting Division Chief, Bureau of Land Management, 20 M Street, Southeast, Washington DC, 20003; e-mail: brittenh@blm.gov. © 2018 AAEP.

1. Introduction

The BLM manages approximately 245 million acres of public lands occurring primarily in the 10 western states with a mission to sustain the health, diversity, and productivity of these public lands for present and future generations. With the passage of the 1971 Wild Free-Roaming Horses and Burros Act (WFRHBA), Congress declared that wild horses and burros were “living symbols of the historic and pioneer spirit of the west” and they “contribute to the diversity of life forms within the Nation and enrich the lives of the American People” (Public Law 92–195, 1971, as amended). The WFRHBA charged the Bureau of Land Management (BLM) with the management responsibility of the majority of wild free-roaming horses and burros on public lands. The Act directs the BLM with the “protection, management, and control of wild free-roaming horses and burros on public lands.” This direction states that all management activities for wild horses and burros shall be at the “minimum feasible level,” that will “preserve and maintain a thriving natural ecological balance” on the lands they reside.

The BLM is a land and resource management agency within the Department of the Interior, managed under the concept of multiple use and conservation. BLM manages wild horses and burros as a resource, and they are the only animal species for which the agency has direct management responsibilities. The goal of the Wild Horse and Burro Program is to ensure healthy wild horses and burros on productive public rangelands to maintain a “thriving natural ecological balance” with other resources and land use values. The purpose of this paper is to provide a summary of the Wild Horse and Burro Program management responsibilities and describe actions outlined in a recent report the BLM submitted to Congress to meet the wild horse and burro challenge.

Overview of BLM’s Wild Horse and Burro Program

Today the BLM manages and protects our nation’s wild horses and burros on 26.9 million acres of pub-
lic lands on 177 herd management areas (HMA) in the west (Fig. 1). The goal of the Wild Horse and Burro Program is to ensure the health of wild horses and burros on healthy public rangelands. The WFRHBA, as amended, contains a variety of tools for managing herd numbers. However, current congressional appropriation riders prohibit the BLM from using all the authorities available in the WFRHBA. Specifically, Congress blocks the sale of wild horses and burros without limitation and has limited the use of euthanasia.

The BLM retains the ability to gather animals from the range but then, if not adopted, sold, or transferred, must care for them the rest of their lives. The cost of holding wild horses and burros in off-range corrals and pastures has increased substantially in recent years and remains the largest component of the program’s budget. In fiscal year 2017, the BLM spent nearly 60% of its budget on the care of animals removed from the range. It costs nearly $48,000 for the care of one unadopted horse that remains in BLM facilities over its lifetime. The cost of caring for 46,000 unadopted and unsold animals currently in holding will cost $1.0 billion over their lifetimes.

In establishing the “Appropriate Management Level” (AML) for wild horse and burros on the public lands, the BLM uses principles of range-
land management to determine the population of wild horses and burros that the habitat can sustain. The BLM seeks to protect rangeland resources, such as soils, water, and vegetation resources, in balance with other uses, including ranching, hunting, recreation, and wildlife habitat. The national AML for wild horses and burros is 26,690 animals across 10 western states. The BLM currently estimates the public lands are home to nearly 83,000 wild horses and burros, more than three times the national AML.

Wild horses and burros have no natural predators that can effectively control populations, and without management, herds can have a mean annual growth rate approaching 20%, doubling every 4–5 years. As herd sizes increase, the forage and water resources from the land become depleted, resulting in loss of body condition (Fig. 2), leading to starvation, dehydration, and death. In their search for food and water, the animals often move onto other public or private lands, or along highways, resulting in safety issues for both horses and burros and humans alike.

The current overpopulation of wild horses and burros also threatens the overall health of western rangelands, degrading ecosystem functions and limiting the forage for domestic and wildlife species. Overgrazing by wild horses and burros has impacted habitat and displaced several wildlife species across the west.

If wild horse and burro populations continue to increase and expand, the impacts to other resources will grow more severe across wide portions of the western public rangelands. Left unabated, the environmental impacts may soon become irreversible and die-offs of wild horses and burros could occur. The groundwork for these unacceptable outcomes has been developing over several years, which is beginning to be observed in certain areas, such as in Nevada. As the 2013 National Science Council report stated in its preface, “it is clear that the status quo of continually removing free-ranging horses then maintaining them in long-term holding facilities, with no foreseeable end in sight, is both economically unsustainable and discordant with public expectations ... and the consequences of simply letting horse populations ... expand to a level of “self-limitation” – bringing suffering and death due to disease, dehydration, and starvation accompanied by degradation of the land – are also unacceptable.” Because of this, the BLM has recently submitted a report to Congress outlining options and strategies to improve the management of wild horses and burros and meet the goals of the program.

2018 Report to Congress
In April 2018, the BLM provided a report to Congress titled “Management Options for a Sustainable Wild Horse and Burro Program,” as directed in the Consolidated Appropriations Act of 2017 (Public Law 115–31). This report details four options for addressing the reality of the situation and management of wild horses and burros on public lands.

Option I
This option focuses on achieving national AML in 8 years (2026) while reducing off-range holding costs dramatically over the first 4 years. In addition, during the first 4 years, the BLM would achieve AML in HMAs that overlap priority habitat for multiple species. This would require making use of all legal authorities included in the WFRHBA as amended (including sale without limitation and euthanasia of healthy unadopted or unsold animals) without the appropriations restrictions Congress has placed on BLM’s management options since the 1980s. This option would also include the use of contraceptives and limited sterilization (spay/neuter) techniques.

Option II
This option focuses on achieving national AML in 10 years (2028) primarily using contraceptive fertility control treatments such as Porcine Zona Pellucida (PZP) and other short-term fertility control and minimal spay/neuter of mares or stallions. Current operations to dart mares with PZP would continue where this treatment is effective (i.e., horses/burros easily approached, smaller populations, and good access). Under this option, off-range costs to care
for animals would significantly increase over current levels because of the increased reliance on off-range care (requiring additional off-range holding space, primarily in form of increasing off-range pastures).

Option III
This option focuses on achieving national AML in 6 years (2024) by using an aggressive removal operation in conjunction with the permanent sterilization of 3,000 mares and stallions gathered annually and later returned to the range. Short-term fertility control would continue in those HMAs where it is effective. Animals that are gathered and not returned to the range would be moved to off-range pastures, thus requiring the continued need to acquire additional low-cost contracted pasture space. Off-range corrals would only be used to prepare animals before shipping to off-range pastures. In an effort to increase adoptions, the BLM under this option would provide a monetary incentive to the adopter of $1,000 to help defray costs for care of the animal and/or training.

Option IV
This option would achieve national AML by 2030 by using an aggressive effort to gather, sterilize, and return animals to the range while also developing the same adoption incentives described in Option III. The goal under this option would be to gather and sterilize up to 18,000 animals per year for the first 5 years and 8,000 in year 6. All these animals would be eventually returned to the range. Because most animals would be returned to the range as a nonreproducing population, off-range holding costs would begin to decrease through natural mortality and expanded efforts to place animals into private care through adoptions, sales, and transfers.

This report also listed other considerations for Congress and tools the BLM could use to meet the intent of the WFRHBA. These include proposing amendments to the WFRHBA such as the following:

- Sale-eligible animals are no longer afforded protection under the WFRHBA.
- Allow for nonreproducing herds, in whole or part, through the use of permanent sterilization methods in areas identified for long-term management.
- Lower the sale-eligibility age of animals from 10 years to 5 years old.
- Eliminate the provision that limits an adopter to acquire title to only four animals per year.
- Reduce the time for an adopter to receive title from 1 year to 6 months.
- Provide the authority to transfer wild horses and burros to nonprofit organizations or other countries for humanitarian purposes or to promote economic development and that such transfers causes animals to lose their status under the WFRHBA.
- Enable the BLM to redirect receipts from sales of horses and apply to on range activities (such as gathers) instead of using those funds for the adoption program.
- Provide permanent authority to transfer wild horses and burros that have been removed from the range to other federal (Fig. 3), state, and local government agencies for use as work animals.

The BLM is pursuing efforts to simplify our environmental compliance by proposing to categorically exclude specific on-range activities such as methods the BLM uses to gather and remove wild horses and burros, short-term fertility control, and permanent sterilization of animals from the National Environmental Policy Act (NEPA) compliance process. When the BLM proposes on-range activities, such as gathers, or the application of short- or long-term population growth suppressants, it requires a lengthy environmental review to comply with NEPA. The BLM has been preparing these NEPA documents for many years, all with a determination of no significant impact on the quality of the human environment (individually or cumulatively). By using categorical exclusions, the BLM will be able to streamline our NEPA compliance and thus saving staff time and funding.

Next Steps and Moving Forward
With the Report to Congress having been submitted, the BLM Wild Horse and Burro Program is moving forward on several fronts for both the on-range and off-range programs. Again, the goals of the on-range management of wild horses and burros are to maintain healthy herds on healthy ecosystems (“thriving natural ecological balance”) while the off-range goal is to place excess wild horses and burros into private care through adoptions, sales, and transfers while reducing holding costs.

On-Range Actions
This fiscal year (October to September), the BLM Director approved a 2018 gather plan to gather and remove up to 10,500 animals. If successful, this will be the most animals removed in the last 5 years (Table 1). Priorities for these gathers are (1) public safety, (2) animals that have moved off their HMAs and are impacting public and private lands (Fig. 4), (3) to achieve and maintain AML, and (4) emergency gathers to respond to deteriorating body condition of wild horses and burros and lack of key horse and burro habitat conditions (lack of water and/or forage) due to severe drought. Whether this gather level is sustainable in future years will be determined by the adequacy of future funding, reductions in off-range holding costs, and an increase in the number of animals placed into private care through adoptions, sales, or transfers.

The second piece to achieving and maintaining AML on the range is the use and expansion of fer-
tility control (Table 2), both short- and long-term (sterilization). Short-term fertility control has been somewhat effective in those HMAs where there is adequate access, the horses or burros are approachable for darting, the HMAs are small, and the population level is close to or within AML. All of these factors combined are relatively rare in a majority of HMAs. So far no “silver bullet” to widely expand fertility control application has been found.

The permanent sterilization of wild horses and burros is very controversial with a segment of the public and vigorously opposed by wild horse advocacy groups. Permanent sterilization of wild horses and burros has only been done in a few instances and has been focused on returning geldings back to the range. At this time, only one study assessing the efficacy and survival rates of spayed/neutered animals and following the social structure of herds has occurred on the Sheldon National Wildlife Refuge.

The BLM has attempted in the past to propose the spaying of mares but has met strong resistance from wild horse groups. In these proposals, the BLM has either withdrawn the proposal to spay mares or the research university conducting the work has backed out of the project. As of July 2018, the BLM is making another attempt to conduct a spay project in Oregon. If this project successfully navigates the environmental review process and expected litigation, this project will be implemented in the fall of 2018.

Table 1. Number of Wild Horses and Burros Removed from Public Rangelands from 2012 to 2017

<table>
<thead>
<tr>
<th>Fiscal Year</th>
<th>Horses</th>
<th>Burros</th>
<th>Total</th>
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</thead>
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<tr>
<td>2017</td>
<td>3,735</td>
<td>474</td>
<td>4,209</td>
</tr>
<tr>
<td>2016</td>
<td>2,899</td>
<td>421</td>
<td>3,320</td>
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<tr>
<td>2015</td>
<td>3,093</td>
<td>726</td>
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<tr>
<td>2014</td>
<td>1,689</td>
<td>168</td>
<td>1,857</td>
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<tr>
<td>2013</td>
<td>4,664</td>
<td>112</td>
<td>4,176</td>
</tr>
<tr>
<td>2012</td>
<td>7,242</td>
<td>1,013</td>
<td>8,255</td>
</tr>
</tbody>
</table>

From www.blm.gov/programs/wildhorse-and-burro/about-the-program/program-data.

Off-Range Actions
One of the actions identified in the Report to Congress was to develop an Adoption Incentive Program to provide adopters up to $1,000 to help defray part of their expenses for care and training. Under this program, which only applies to adopting untrained wild horses and burros, the BLM is proposing to reduce the adoption fee from $125 to $25. At the time when the...
animal is adopted, the adopter will receive a $500 incentive payment shortly after the animal is adopted and an additional $500 at the time when title is transferred to the adopter. A member of the public can adopt up to four horses and/or burros per year because a person is limited to receiving four titles in one year. It is hoped that this incentive program increases adoptions to help reduce BLM’s holding costs.

Other programs the BLM is pursuing is to streamline transfers of animals to other federal agencies and state and local governments as work animals. Several federal agencies, such as the National Park Service, Border Patrol, and military utilize horses as work animals. Local law enforcement are beginning to use wild horses for their activities as well.

Besides the transfer program, the BLM is exploring the opportunity to move horses outside the United States as work animals for humanitarian purposes or to promote economic development.

The BLM is committed to finding solutions to achieve and maintain a long-term sustainable wild horse and burro program that meets the agency’s mission to sustain the health, diversity, and productivity of the public lands for the use and enjoyment of present and future generations. BLM will need the help from all stakeholders to solve the overpopulation of wild horses and burros on the range while reducing off-range holding costs. This issue has been developing over several years and it will take a sustained multiyear effort to solve the problem at hand, with the assistance from all stakeholders to ensure that these “living symbols” remain part of our national landscape for generations to come.

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

Conflict of Interest
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References
A Review of Contemporary Contraceptives and Sterilization Techniques for Feral Horses

Albert J. Kane, DVM, MPVM, PhD

Porcine zona pellucida immunocontraceptives have received the most attention and use over the past 40 years, but other treatments such as a gonadotropin-releasing hormone (GnRH) vaccine are also available. Optimization of these treatments as well as the development of other molecular approaches, intrauterine devices, and surgical techniques are ongoing. Author’s address: U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Veterinary Services, 2150 Centre Ave., Bldg B MS2E6, Fort Collins, CO 80526; e-mail: albert.j.kane@aphis.usda.gov. © 2018 AAEP.

1. Introduction
Since the late 1970s, researchers have sought a safe and effective equine contraceptive to help reduce population growth rates of feral horses (Equus ferus caballus) and burros (E. asinus). A treatment that is safe, practical, effective, and long lasting has not yet been developed. Even after a treatment is developed that is effective for individual animals, there remain significant hurdles at the population level that must be overcome to reduce population growth rates. This commentary provides a brief review of past research efforts to develop contraceptives for feral horses as well as a discussion of the contraceptives and sterilization techniques currently available.

2. Review
Early fertility control efforts focused on both male and female contraception. However, as early as 1980, scientists with the National Research Council, part of the National Academies of Science, recommended that wild horse contraceptive efforts should focus on reducing fertility in mares. They recognized the polygynandrous nature of feral horses where multiple males may breed the same or multiple females. Although it is true that wild horses live in harems that include a dominant stallion, much of the breeding may also be done by other stallions, and harem structures are fluid over time. It has been demonstrated that up to one third of foals may be sired by stallions that are not affiliated with a mare’s band.3

Steroid Hormones to Vaccines
Early contraceptive studies in stallions and mares used steroid hormones to alter fertility. Although there was some success in mares, the treatments were cumbersome to administer, and there were concerns about the potential for persistence of the hormones in the food chain and the environment. At approximately the same time, studies were done with surgical vasectomies applied to harem stallions. There was a small effect noted in one of the two groups studied, but it was short lived. The researchers concluded that, although it may be effective at the individual horse level, the efficacy of vasectomizing males for population growth suppression over time was doubtful.
As attention turned away from using steroid hormones to alter fertility, porcine zona pellucida (PZP) vaccines were developed in laboratory rodents and later applied to horses.\(^4,5\) The PZP vaccine contains a glycoprotein antigen harvested from pig (Sus scrofa domesticus) ovaries. When mixed with a powerful adjuvant (in most cases, it is emulsified with Freund’s adjuvant), it stimulates the mare’s immune system to make antibodies to ZP proteins. These antibodies block fertilization of the egg and over time bind to zona proteins in the ovary, causing it to shrink and become nonfunctional. The most widely used PZP vaccine is Zonastat-H\(^5\). This liquid immuncontraceptive can be hand injected or darted into mares. When a booster shot is also administered about 30 days later and about 1–2 months prior to the breeding season, it is highly effective at preventing conception for one year, with only about 10 to 20% of treated mares foaling each year. In smaller herds where the number of animals is at or very close to the appropriate management level (AML), Zonastat-H can successfully reduce or even eliminate the need to gather and remove animals over time.

The Bureau of Land Management (BLM) is currently using this approach in several herds.\(^6\) The biggest limitation to this treatment is that it must be administered every year. Most animals on BLM ranges cannot be approached closely enough to allow darting, and repeated annual roundups to allow hand injecting the treatment get more difficult with each repetition, usually becoming impractical and ineffective after two or three iterations. Another limitation of this approach is how long it takes to achieve desired population numbers, called the AML by BLM, when herds are even modestly above the desired numbers. The so-called “Assateague prescription,” where the majority of mares were darted every year,\(^7\) was eventually effective at achieving population targets on a small barrier island, but it took 13 years before a decline in numbers was achieved and several additional years before AML was achieved. That population of 156 horses started in 1993 only 30% over the desired AML of 120 horses, had 143 horses after 13 years, and today has about 90 horses. For comparison, many wild horse herds managed by the BLM in the west are currently at levels more than 100% greater than AML.

The quest for a longer-lasting PZP treatment began about the same time that Zonastat-H was being developed. An early study of the pelleted “PZP-22”\(^8\) treatment was most promising, with only 6–18% of mares with reported foaling in the first two years of the Clan Alpine study and 30–40% foaling in years 3 and 4.\(^8\) Unfortunately, this level of success has never been repeated with several captive and free-ranging trials reporting 25, 30, or even 70% foaling in the first two years following treatment. The reasons for this poor performance mostly remain a mystery. Recently success of 15–40% foaling over a three year period was reported with reformulated PZP-22 after additional booster treatments,\(^9\) but whether or not this can be repeated remains to be seen. Currently, PZP-22 is the treatment used most frequently by the BLM, because, at the very least, it usually provides one year of good efficacy without requiring a 30-day booster shot, and when boostered a year or two later, efficacy should improve.

SpayVac\(^4,9\), another formulation of PZP developed to offer longer lasting efficacy, uses similar PZP antigens with a unique liposome technology expected to provide several years of efficacy. As with PZP-22, an initial study of the treatment was promising.\(^10\) However, subsequent trials aimed at demonstrating long term efficacy in a captive pasture breeding setting could not duplicate the same results and, in fact, showed reasonable efficacy in one year (15% foaling) but poor efficacy over time, with up to 70% of treated mares foaling.\(^11\) Although this vaccine is not commercially available at this time, the proponents of the product have regrouped and hope to conduct testing of a new formulation of SpayVac in the future.\(^12\) Although this product shares the same limitations inherent to the PZP antigen as Zonastat-H and PZP-22, in some species, including occasionally horses, it seems like it could be long lasting or even permanent. The reliability of the newly formulated product will need to be established in captive breeding trials with horses before one might have the confidence needed for field applications.

**Gonacon**

At this time, there is only one other contraceptive product available for use in horses. Gonacon-Equine\(^5\) is a vaccine that acts against gonadotropin-releasing hormone (GnRH), a hormone critical to fertility. The vaccine was formulated and registered with the Environmental Protection Agency as a one-shot treatment that was thought to provide good multiyear efficacy. Captive pen trials resulted in good efficacy (6% foaling) the first year,\(^10\) but, again, the efficacy of a single treatment in field trials conducted with feral horses at Theodore Roosevelt National Park never reached that level of effectiveness, with about 50% of animals foaling the first and second years.\(^13\) Fortunately, with a booster treatment as much as three years following the initial shot, efficacy improved dramatically, with 0% of mares foaling a year later and around 15% foaling in the following two years. Like PZP vaccines, Gonacon can be hand injected or darted. It has two advantages in that it does not require mixing in the field and is more stable when stored. The longer term efficacy of Gonacon seems more promising than the PZP vaccines at this time; however, optimal booster schedules are still being investigated. The BLM has used Gonacon in one small pilot project on the range, and the early results are encouraging. Gonacon treatment that includes a
booster may be one of the best options currently available for the contraception of feral horses.

Intrauterine Devices
After many years of focusing primarily on PZP and GnRH technologies, other contraceptive approaches are now being investigated for feral horses, with support from the BLM. In addition to injectable treatments, new intrauterine devices (IUDs) are being tested. Early studies of IUDs were promising, with reports of over 80% retention and efficacy with no negative effects on mare health. However, once again, when additional captive breeding trials were done with the same design (as well as other more sophisticated designs that was promoted as effective with 100% retention), the results were disappointing, with 60–100% of the devices falling out soon after stallions were allowed to breed the mares. A current BLM-supported study of a new IUD has had some success with a redesigned product that seems to offer better retention in the presence of stallions. Data are still being obtained at this time to demonstrate retention, efficacy, and safety over a period of years. IUDs have the advantage of being almost 100% effective as long as they are retained. They appear to have no long-term negative effects on the mare’s health or the uterus, and they could be 100% reversible if removed. They do have the distinct disadvantage that they can only be inserted into nonpregnant mares and most feral horse mares of breeding age are pregnant for most of the year.

Surgical Sterilization
Surgical sterilization, once considered taboo for feral horses because it is permanent, is also again being considered as a means of reducing population growth rates. For stallions, the same limitations of polygynandry that became apparent back in the 1980s are still present. It seems unlikely that castrating or vasectomizing only some portion of the more dominant males in a herd will significantly slow population growth over a period of several years, because enough stallions will still be present to eventually breed all the mares present. However, a saturation approach where some high percentage (e.g., 80–95%) of stallions are sterilized remains untested.

In their most recent review of the science behind feral horse contraception, the National Academy of Sciences recommended chemical vasectomy as a promising technique. Despite acknowledging that it was not yet proven, they felt that it should not be difficult to adapt to feral horses. Unfortunately, this does not seem to be the case. When chemically vasectomized horses were reexamined after a recent study performed on the Sheldon Wildlife Refuge, it was revealed that the chemical vasectomies failed to block sperm transport in any of the dozens of animals treated. Although it should be possible to develop and use a technique for chemical vasectomy, it seems to offer little advantage over the surgical procedure, which has been done with individual horses but remains unproven at the population level. The fact that a small number of fertile stallions can impregnate many mares suggests that any form of vasectomy is unlikely to be an effective means of long-term population growth suppression.

The consideration of surgical sterilization is not limited to stallions but also extends to spaying and tubal ligation procedures for mares. There is no established procedure for tubal ligation in mares. It is not something that is called for among domestic horses and has not been developed or tested for feral horses. Spaying, although not as common as castration, is done in domestic horses and has been done with feral horses. The procedure in horses is much more difficult than it is in cattle and not as routinely practiced as spaying dogs and cats, for example. It is almost never done to pregnant domestic horses, so the safety and practicality of spaying feral horses on a large scale, particularly while pregnant, remain mostly untested.

Feral mares were spayed on the Sheldon Wildlife Refuge, with a report of fewer foals born to harems that included spayed mares and vasectomized stallions, but it remains to be seen if similar results could be obtained in other places when spaying alone is done on a large scale in the context of typical BLM roundups. Yes, individual mares can be spayed, but can practitioners do it safely on a large scale with pregnant mares and will it help achieve the goal of controlling population growth rates? The BLM has attempted to answer some of these questions with applied research, but these questions remain unanswered largely due to litigation that prevented the projects from getting started.

3. Discussion
We are often asked, why hasn’t anyone developed the ideal contraceptive for feral horses when BLM has been supporting this research for over 40 years? The answer is perhaps that an ideal contraceptive is an unreasonable expectation, for any species. Safety for mares, unborn colts, and the environment are paramount, but is it really reasonable to expect a one-shot, long-lasting, predictably reversible contraceptive that has no behavioral effects for horses when modern science has never even developed such a treatment for dogs, cats, or people? The emphasis for reproductive research in the domestic horse world has always been getting mares pregnant, not trying to prevent pregnancy. Until the last few years, there has been very limited funding for contraceptive research for horses, with more funding obligated by BLM to research projects in the last few years than the previous 40 years combined. From where we started in the 1970s, researchers have made significant discoveries and improvements in contraceptives for feral horses.

The desperate need for results in the field and the limited funding available have meant that several
treatments were advanced to field trials or management use in the field after only one test under more limited conditions in captivity. It is not uncommon for treatments that work in controlled laboratory or clinical settings not to work as well when applied on a larger scale in the field. Unfortunately, we have seen this with feral horse contraception on several occasions. Were the early studies flawed by unblinded, biased outcome assessments? What about the blinded (SpayVac) studies that also could not be replicated? Was it the biological variation in the PZP itself, changes in the adjuvants, or preparation of the vaccines? All of these factors are the reason that research science prefers to look for replication of results by different investigators under expanded conditions before taking treatments to management application in the field. However, these are luxuries that feral horse contraceptive research did not have.

The pressure and the push have been to take treatments to the field as soon as they offer some legitimate promise of success. The upside would have been faster results where they were needed most. The down side was several treatments did not work as well as expected when applied on a large scale. These challenges were added to the practical limitations and expectations of trying to apply darting programs to the typically vast western rangelands that span not thousands of acres but hundreds of thousands of acres. Darting programs can work on a small scale where a hundred or so named animals can be approached to within 30 or 40 yards. However, where 10 times as many horses might roam on land areas 30 times larger and the horses cannot be recognized as individuals because they mostly look alike, this approach is not practicable. Most often these animals cannot be approached to less than hundreds of yards. Under these more typical conditions, darting programs are not likely to succeed. Despite all this, there have been small scale successes on some BLM lands; the Pryor Mountains Wild Horse Range and the Little Book Cliffs, McCullough Peaks, and Spring Creek Basin Herb Management Areas come to mind.

4. Conclusion
The history of feral horse contraception research is one of desperate need, ambitious (perhaps sometimes unreasonable) goals, and the passionate pursuit of a solution by a handful of investigators challenged by limited resources as well as the biology of the endeavor. Unfortunately, despite the many advances that have been made, a contraceptive solution that is safe, practical, and effective for most herds on typical western herds is not in hand. Right now, feral horse contraception research has better levels of funding than ever before, with major universities more engaged than ever and new, never previously conceived molecular techniques being investigated. Nevertheless, progress will likely be slow. For every idea that advances to the next level of investigation, two or three others will fail. Despite the desperate need, if we can maintain current research funding levels, we are years, likely more than a decade, away from a contraceptive solution to the challenge of significantly reducing feral horse population growth rates on western rangelands. The good news is it is still conceivable, and there are still some very bright and passionate scientists working on solutions that will make a difference.

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

Conflict of Interest
The Author is an employee of the U.S. Department of Agriculture, Animal and Plant Health Inspection Service (APHIS), Veterinary Services and serves as an advisor to the APHIS/BLM Wild Horse and Burro Partnership that is supported by funding provided from the BLM to the USDA APHIS. Gonacon is manufactured and sold by the USDA APHIS Wildlife Services, but the author has no financial or employment involvement with this branch of the USDA APHIS or any other companies that manufacture or sell products that figure prominently in this review.

References and Footnotes


\[\text{Gonacon-Equine® USDA APHIS Wildlife Services, Ft Collins, CO 80526.}\]

\[\text{Zonastat-H® Human Society of United States, Washington DC 20037.}\]

\[\text{PZP-22 John Turner, Univ of Toledo, Toledo, OH 43606.}\]

\[\text{SpayVac® SpayVac for Wildlife Inc, Sidney, BC Canada.}\]
Managing Healthy Wild Horses and Burros on Healthy Rangelands: Tools and the Toolbox

Callie Hendrickson

The Wild and Free-Roaming Horse and Burro Act (WFHBA) of 1971 authorized the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) to manage feral horses (Equus ferus caballus) and burros (E. asinus) on public lands in the United States. The special issue of Human–Wildlife Interactions, Special Topic: Wild Horse and Burro Management explored, in-depth, the ecological, policy, political, practical, and sociological issues pertinent to the BLM and USFS management of wild horses and burros. In this commentary, I summarize the pros and cons of the available contemporary policy and management options, the tools in the BLM and USFS toolbox, that can contribute to achieving the intent of the WFHBA. Ultimately, it will be up to Congress to choose which options are in the best interest of the American public and our natural resources. Author's address: White River & Douglas Creek Conservation Districts, Meeker, CO 81641, USA; e-mail: callie.districts@gmail.com. © 2018 AAEP.

1. Introduction

The Wild and Free-Roaming Horse and Burro Act (WFHBA) of 1971 gave the Bureau of Land Management (BLM) and the U.S. Forest Service (USFS) the legal responsibility to manage feral horses (Equus ferus caballus) and burros (E. asinus) in specific locations on public lands in the United States.1 These agencies are legally required to manage wild horses and burros (WHBs) in concert with other legal multiple-uses and laws governing the land management agencies.

The BLM and USFS have been arguably successful in managing multiple-uses of public lands, but implementation of the WFHBA has proven to be among the biggest challenges to sustainable management. In 2008, the U.S. Government Accountability Office (GAO) reported that “If not controlled, off-the-range holding costs will continue to overwhelm the program.” At that time, there were 30,000 horses in holding facilities.2

Today, the BLM alone is struggling to manage approximately 127,000 horses and burros (animals) with designated lands that will only support 27,000 (Table 1). Approximately 45,000 of the animals reside in holding facilities, costing the American taxpayer $50 million per year and >$1 billion for the remainder of those 45,000 lives.3 Currently, the remaining 82,000 are left on the range to compete with the wildlife, livestock, and vegetation for survival.4

All public land uses, other than for WHBs, are managed to maintain the balance between the uses and to ensure the land health standards are met. Wildlife are hunted, livestock are regulated and required to use rotational grazing and/or removal, recreation is permitted and restricted, and oil and gas are regulated. After WFHBA was passed, the federal agencies managed WHB populations through gathers and removal. The gathers now are largely contested in the courts, and the costs of holding

NOTES

WHBs in off-range facilities consume most of the WHB Program budget.3

The papers in the Human-Wildlife Interactions special issue synthesize the science, confirming that the lack of management of WHBs is detrimental to the land, WHBs, wildlife, livestock, and rural communities. Unmanaged WHBs are now causing irreversible damage to fragile western landscapes. The way the current WHB Program is being managed is unsustainable.3

2. Options and Potential Solutions

Congress, or rather society, has tough decisions to make to address one of the most significant environmental issues threatening U.S. public lands. Will we choose to sacrifice the land, water, native wildlife resources, and the health of the WHBs to allow the unchecked population growth? Will we choose to accept the exponential growth of WHB numbers over sustainable economies of local communities who work diligently to provide food, fiber, and energy to the American population? Or will we choose to manage WHBs in a sustainable manner that will be in balance with all the required multiple uses as well as maintain a healthy population of horses and burros on public lands? The following is an overview of the basic options, including the pros and cons, to answer the above questions.

Option #1: Leave Most Horses on the Range

We gather and remove WHBs only on an emergency basis (imminent starvation and dehydration of horses where visible to the public), leaving the excess horses and burros on the rangelands.

**Pros**

1. Financial burdens (of gathers and holding) are reduced.
2. Horses would remain free-roaming.

**Cons**

1. Animals (including horses and burros) will die of thirst and starvation because unmanaged populations double every 4–5 years, causing irreparable range degradation and desertification, which will become the norm (Fig. 1).3

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**Table 1. Wild Horse and Burro (WHB) Program Data Pulled from the Bureau of Land Management (BLM) 2018 Website. Accessed July 27, 2018.**

<table>
<thead>
<tr>
<th>Population</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>On-range population (March 2018)</td>
<td>81,951</td>
</tr>
<tr>
<td>Off-range population (June 2018)</td>
<td>44,730</td>
</tr>
<tr>
<td>Total BLM managed populations</td>
<td>126,681</td>
</tr>
<tr>
<td>Ecologically based appropriate management level (AML)</td>
<td>26,715</td>
</tr>
<tr>
<td>Total estimated population above AML</td>
<td>99,966</td>
</tr>
</tbody>
</table>

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**Fig. 1. Animals (including horses [*Equus ferus caballus*] and burros [*E. asinas*]) will die of thirst and starvation because unmanaged populations double every 4–5 years, causing irreparable range degradation and desertification, which will become the norm (photos courtesy of the Bureau of Land Management and Savannah Sturm).**
2. Excess horses negatively impact native species such as the greater sage-grouse (Centrocercus urophasianus).5

3. Horses and burros will expand further beyond legal boundaries, negatively impacting even more rangelands.

4. Single-use management of federal land and disregard for the economies of local communities will occur.

5. There would be a violation of Congressional mandates for responsible management of public resources.

Option #2: Gather and Place Excess Horses and Burros in Holding Facilities for the Remainder of Their Lives

Conduct massive roundups to remove all excess WHBs (those above the Appropriate Management Level [AML]) from the rangelands within the next 2 years and place them in short- or long-term holding facilities. Current costs are approximately $2 per day per horse in long-term holding (pastures) and $5 per day per horse in short-term holding (corrals).4 Current holding facility capacity is 59,748 (Fig. 2). Additional capacity would likely cost more per horse due to demand. The BLM estimates the cost of holding 47,000 horses over the remainder of their lives would be over $1 billion without any additional horses or burros brought into the holding system.3,6,11

Pros

Removal of excess WHBs would protect rangeland health and reduce competition and stress on wildlife and other multiple uses of the federal lands.

Cons

1. The cost to taxpayers for feeding and caring for 100,000 excess horses until each dies of natural causes would be an average of $30,000 (lifetime) for each animal and would be approximately $3 billion over the next 20 years.

2. Horses would have to be living in confinement rather than in their typical habitat.

3. Demand for feed consumed by 100,000 excess horses could increase the cost of feed for livestock, increasing the cost of food to the American public.

4. Continued cost and stress of gathers would occur.3,6
Option #3: Increase Adoptions

The adoption demand over the past 5 years has averaged 2,700 per year.

Pros

1. Fewer horses would be in holding, saving taxpayer dollars.
2. Fewer horses would be on the range, so they would not be contributing to the degradation.
3. Individuals could enjoy the animals, and most adopted animals would have a good home.

Cons

1. Demand does not meet the current and growing supply (2,700 adopted annually versus current supply of 100,000 excess WHBs).
2. Continued cost and stress of gathers would occur.
3. FY2016 adoption efforts cost the taxpayer $7,375,000 to adopt 2,912 animals, which is $2,532 per horse/burro.2,6

Option #4: Fertility Control

Including all short- and long-term fertility control tools would likely require significant gathers to treat animals.

Pros

1. Porcine zona pellucida (PZP) and other short-term vaccines may reduce the reproduction rate in small herds that receive treatment on an annual basis.
2. Sterilization would eliminate the need for additional gathers and treatments of that animal.
3. When a Herd Management Area (HMA) is within the AML, fertility control will help to maintain that number.7

Cons

1. The current 2 year or more vaccines are unreliable.
2. Although fertility control may reduce population growth if used on the majority of mares, it does not reduce populations, which is currently required to save the ecosystem from degradation and some horses from starvation/dehydration.
3. It is impractical to administer the short-term vaccines on a meaningful scale with large land masses, elusive horses, undocumented horses, and lack of funding and manpower.6,8,9
4. Impacts to the habitat of native species continue.

Option #5: Remove Livestock from the HMAs

Livestock grazing has already been curtailed in some HMAs, and emergency gathers have continued because the horses are starving.10

Pros

There would be forage for more horses in the short-term.

Cons

1. In 4 years, there will be double the number of horses on the HMAs, filling the void from livestock, and 4 years later, the number will have doubled again with a need for removals of a much greater number of horses.
2. Yearlong (unmanaged) grazing of horses replaces managed grazing by livestock, therefore causing significant impacts on the habitat of threatened and endangered species.
3. In times of drought, the BLM will not be able to rely on reducing livestock animal unit months to support horses and wildlife.
4. There is significant reduction of already scarce water resources for the horses without ranchers hauling water and/or maintaining water structures at personal expense.
5. There are negative economic impacts to the rural and state economies because ranching is a primary economic driver.
6. Wildlife and other multiple uses would be negatively impacted by more horses.3,6,10

Option #6: The Full Toolbox—Full Implementation of the WFHBA

Each HMA is unique and should be managed accordingly. This option would allow the agencies to use the most appropriate “tool in the toolbox” for each HMA, ensuring approximately 27,000 WHBs remain free-roaming on the designated rangelands with good forage and water. The full toolbox option includes removals of all excess WHBs from the range, offering excess animals for adoption, and those that are not adopted to good homes would be sold without restrictions or euthanized. Fertility control, including sterilization of mares and stallions, would continue to be researched and implemented on a larger scale once the numbers are down to the AML within the respective HMA.

Pros

1. The number of excess horses and burros on the range would be significantly reduced, and the rangeland could begin to recover for the benefit of all uses.
2. Holding costs of approximately $50 million per year would be eliminated and could be used to rehabilitate some of the degraded rangelands.
3. Individuals/groups wishing to protect the horses could purchase and care for them with their personal financial resources.
4. Entrepreneurial opportunities would exist for large landowners to care for privately owned WHBs.
5. The WHBs that are not purchased by those wanting to protect them could provide protein to people in need or people who choose to use them for those purposes.
6. All these tools are in accordance with and in the spirit of the WFHBA as written.
7. Humane euthanization would replace suffering from starvation and dehydration of WHBs on the rangelands.

Cons

1. There would be public outcry from those who do not believe in unrestricted sale and/or euthanasia.
2. Some adopted and sold horses may not receive the best of care in the hands of well-intentioned but uninformed individuals who adopt or purchase them.

Which options/tools will Congress and an informed public choose? I remain hopeful they will provide the full toolbox to honor the legacy of the WHB by ensuring they are treated humanely and with dignity, the ecosystem can thrive while supporting all the multiple uses, and tax payer dollars are prudently expended.3,6

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Conflict of Interest
The Author has no conflicts of interest.

References

How to Develop an Equine Veterinary Facility All-Hazards Sheltering and Evacuation Plan

Rebecca Husted, BS, PhD*; and Rebecca McConnico, DVM, PhD, DACVIM

1. Introduction

Natural disasters (flooding, wildfire, blizzards, high-wind events, earthquakes) and local emergencies (contagious disease outbreak, barn fire, HAZMAT evacuation, power failure) can detrimentally affect equine facilities with unpredictable frequency, but often occur relative to geographic location or climate (Fig. 1). Facilities that plan and prepare are more capable of overcoming the challenges ahead in a more organized and predictable manner. “In preparing for battle I have always found that plans are useless, but planning is indispensable.” —Dwight D. Eisenhower.

Realization that this applies to everyone just comes down to simple math. An owner responsible for eight horses, owning a three-horse capacity trailer that must move their horses 100 miles to safety—it would take minimum three trips and 500 miles of driving to evacuate all the animals. Extending the math, in normal 55-mph traffic, that’s 9 hours of driving (not including fuel and bathroom stops, loading and unloading at both ends, coordination face to face, and evacuation traffic speeds). At 20 mph, that would be 25 hours—a full day to evacuate (assuming law enforcement allows return trips). When owners and veterinarians become aware of these vital statistics, they become champions of planning for disasters for their businesses.

Risk identification, reduction, and mitigation of disaster affects on your clinic start with a specific written plan for an all-hazards approach to sheltering and/or evacuation as crucial parts of effective equine facility management. Practitioners need to develop effective and efficient plans for their own business, setting the example for their clients and giving the veterinarian personal experience, which makes them better able to advise their clients. Thereby, they increase the resiliency of their entire agricultural community by integrating animal issues into an overall emergency management strategy for the community.¹

Domestic horses are totally dependent on humans to care for them, especially in emergencies and disasters. When humans took horses out of the wild and placed them in confinement for convenience (Fig. 2), we took away their ability to use millions of years of evolutionary skills and instincts to keep them out of danger dealing with predators and innumerable disasters. In the wild, horses can pick the safest place to get out of storms, run away from
wildfire and flood, or patiently endure the blizzard and dig for food through the snow. In the modern world, they have no freedom to get out of fences and stalls when threatened. In a December 7, 2017 wildfire incident in California, 30 horses padlocked in their stalls at the barn did not survive the fire. Early evacuations are key to ensuring these tragedies do not occur, and humans must do the planning and facilitation. A plan is far more comprehensive when done ahead of time instead of under duress in the face of a disaster.

No matter the size of your facility—whether treating backyard horses in a pole barn or managing an attached barn with a treatment clinic featuring high dollar show horses, facility owners are expected by their clients to have evacuation or shelter-in place plans for every conceivable type of disaster. Realistically, having specific disaster plans for every imaginable and unimaginable imminent disaster is difficult, expensive, and ranges into the impossible. This paper will highlight simple ways to implement plans for disaster mitigation and response for a facility of any size, which can be built upon as the clinic gains experience then complements services and features.

2. Materials and Methods

Preparedness for emergencies and disasters involving horses must begin at the local level as a two-pronged effort: 1) animal facility owners taking responsibility for animals under their care, and 2) emergency services management personnel preplan for evacuation and sheltering considerations of large groups of animals within the civil jurisdiction, state or region. Planning for all hazards’ “worst-case scenario” (Fig. 3) incidents will expand community awareness for disaster scenarios, and may even dictate the future of the practitioners’ business success. Example: before Hurricane Irma (2017) it is estimated that 20,000+ horses were evacuated out of South and Central Florida, along with over 6.5 million people living in mandatory evacuation zones. In an unprecedented action, the Florida Department of Agriculture and Consumer Services, Division of Animal Industry, temporarily suspended intrastate movement requirements for the transportation of animals from Florida, and border states waived their interstate import requirements for pets and livestock leaving the expected impact areas of Hurricane Irma. This allowed veterinarians in the state to concentrate on disaster preparation and mitigation for their businesses, instead of fulfilling innumerable health certificates for travel.

There are two levels of disaster preparedness for each facility to achieve:

1. Personal preparedness (the practitioner’s staff and family is capable of taking care of
themselves, their loved ones and personal animals) to be able to evacuate, or shelter in place.

2. Business preparedness (resumption/contingency planning for the practitioner’s facility as a business, whether a horse boarding facility, veterinary clinic, and/or breeding farm.)

It is not always the impact of the original event that is worse, it can be the chaos, confusion, and forced change in routines that occur afterward. For example, if a geographical area that normally does not receive winter precipitation is subjected to a heavy snowfall or ice, access to these areas will be restricted and livestock may go without hay, feed, or water. Long-term damage to roads and bridges from flooding makes travel to animal locations impossible due to impassable roads. Or, if a reportable disease was brought into your treatment facility and resulted in quarantine of all animals housed there, how would that affect your daily business (Fig. 4)? For example, in 2016 the University of Georgia Large Animal Veterinary Teaching Hospital was quarantined and shut down for cleanup from an equine herpesvirus-positive horse for 20 days.3

Legal action from clients can threaten the business itself, and should be part of business resumption and continuity planning. Example: Colorado State University’s (CSU’s) Equine Reproduction Laboratory caught on fire in 2011 (Fig. 5) and highly valuable genetic material was not able to be saved from fire damage. Insurance did not cover the cost of genetic material destroyed in the fire, but breeders who lost frozen embryos, sperm, and eggs were offered a $1,000 credit for future reproductive services by CSU. One client sued in the amount of $1 million dollars for damages in loss of frozen semen in the fire, and it went all the way to the Colorado Supreme Court of Appeals for resolution.4,5

It is the practice owner’s responsibility to have a functional disaster plan to care for personal needs (family) and clinic staff and patients (business). Don’t forget a crucial part of the resiliency built into a plan is to ensure their members have a solid plan for their own families and animals so that they can assist with business planning—in so many past disasters where the plan was built on having staff present—the employees end up solving their own issues, they were not available to help. This has happened to numerous communities that depend on police and volunteer firefighters—they were so tied up unraveling the disaster impacting their own family that they didn’t report to work. Client horse owners will expect the clinic/facility owner to have a functional disaster plan, they should expect to sign a waiver with the details of how it is expected to solve evacuation or shelter-in place issues as a part of normal board and care.

Fig. 2. Animals in modern enclosures cannot escape flooding, wildfire, or barn fires. This is just one of the thousands of horses that were found dead in their stalls post-Hurricane Katrina (2005) across Louisiana, Mississippi, and Alabama. Failure to evacuate to high ground ahead of large storms causes agricultural losses in all aspects of the industry. Photo courtesy of Jay Addison.
The plan should consider how would operations at your reproduction barn, or the daily horse management at the clinic be affected if power was lost for just one day? What if the outage lasted for a week? What is the plan when power goes out during the bone-chilling grip of winter—to provide fresh water, power, sufficient forage and care for animals under a vet clinic/farm manager’s care? In a drought or extreme heat? Local emergencies of this type are very common and should force responsible practitioners and horse owners to think through the various aspects for durability of animal care (and continuity of business).

Self reliance is a crucial part of domestic emergency management policy. Civil jurisdictional emergency management officials may provide assistance to affected animals and clinic owners in the geographical disaster area, but only after providing life safety to humans as their main priority. Hours, days, and weeks will go by before animals move up the priority list for response actions. Thus in reality, practitioners and facility owners should take personal responsibility to prepare a plan. Don’t expect others to evacuate/attend to animals under your care—this is a potential litigation issue. Representatives from the veterinary industry and horse owners should be included on local emergency management planning committees to communicate the problems animal owners encounter, their options, how they affect the community, and provide timely and factual information (location of shelters, proactive actions, disease outbreaks, etc.) to the media. These proactive actions by practitioners can minimize the amount of time and expense to bring equine clinic operations back on-line and increases goodwill with your clients that will need your expertise after the disaster. Good plans preserve more of the facility, equipment, most valuable animals, as well as the clinic owner’s peace of mind. Making these “emergency” practices and prevention procedures a part of your daily routines at a facility soon builds other benefits—“practice managers noticed improvements...
in efficiency, confidence in their ability to respond appropriately, and increased efficiency born of a workable schedule.\textsuperscript{a}

A literature search found few studies of emergency management planning for horses, horse facilities, or equine veterinary facilities. One survey of horse farms in Madison County, Kentucky, collected data about equine evacuation planning, in case of a natural disaster.\textsuperscript{b} Farms ranged in size from 0.5 to 500 acres, nine breeds of horses and 65.5\% commercial. Most farms had multiple sources of water for livestock, and some kind of shelter for horses. None had experienced an evacuation, but 11.5\% had plans developed. All had some equipment for evacuation, but help would be a problem in on 57.7\% of the farms. Estimates averaged that five horses at a time could be moved from the farms to a wide variety of evacuation sites; family-owned land, 25.9\%; friends, 29.6\%; boarding stables, 11.1\%; a designated evacuation area, 7.7\%. If horses were to be left on the farm their concerns were water and feed (61.5\%), survival and wellbeing (26.9\%), none mentioned theft. From a safety standpoint, only 70\% of the horse owners/managers considered their families first priority, and animals secondary.

Other studies found that people who leave pets behind during disasters tend to be less responsible owners in general, scoring lower on pet attachment scales and often failing to provide normal vaccination, sterilization, and annual vet care for their animals. Approximately 30\% to 50\% of pet (cat and dog) owners leave their pets behind during evacuation, even with advance notice to leave.\textsuperscript{c} (There are no published studies for horses.) Many of these same owners later attempted to “rescue” their animals, ignoring security barriers, in order to provide food and check on them. On the other hand, even under mandatory evacuation, some people will not leave their animals, and some have died making this choice.\textsuperscript{b}

Survey of emergency managers have shown that in states where large disasters occur more frequently, people have better plans for their horses and pets. These studies give veterinarians, emergency responders, and managers a perspective into the challenges faced in getting the equine community involved in disaster planning and client education.

Lessons Learned From Hurricane Katrina for a Successful Equine Disaster Response.\textsuperscript{b}

- Animal response activities need to be coordinated locally, regionally, state-wide, and nationally through the use, as much as possible, of the National Incident Management System’s Incident Command System.
- Communities should be educated on means to work together to establish community-wide disaster response plans that include animal management considerations. Veterinarians are crucial to this process.
- Incident Command System is important for successful disaster response, personnel flexibility, and communication at all levels of the response is also important.
- Even though state and local jurisdictions are required to participate in the National Animal Plan, Incident Command System leadership should anticipate that most volunteers will not have a working knowledge of disaster management procedural processes. State, regional, and local leadership must develop processes to effectively use minimally trained volunteers during disaster response.
- During any disaster, a public information officer must be appointed to process, filter, coordinate, and provide consistent and accurate...
The animal-owning public and animal care professionals must be encouraged to have an evacuation plan for their families, including their pets and other animals.

● The animal-owning public must be encouraged to obtain knowledge of and become involved with local and regional disaster activities critical for future disaster responses.

● Permanent forms of animal identification should be encouraged to assist with accurate animal recognition and owner-animal reunion.

● Disaster responders and veterinarians must realize that the immediate goal during disaster response efforts is to provide basic animal medical and husbandry needs.

● Potential disaster assistance volunteers should be encouraged to undergo Incident Command System training, so they will understand and appreciate how working outside of this system hampers response.

Prevention/Mitigation is the permanent changes made to minimize effect of a disaster, for example, adding a smoke detection alarm and sprinkler system, using reduced flammable materials to build a clinic treatment barn, moving hay and other forage or shavings combustibles to a separate barn away from the clinic, or providing 25 m of defensible space around the facility to prevent wildfire losses with FireWise designs. Mitigation could include motivating clients and local community to place storm shutters on glass windows, buy a generator, add a sprinkler system or use nonflammable materials when building a barn, increase culvert size in road crossings to prevent washouts, add secondary fencing to prevent loose animals from getting to the road, etc. Information is available in the Local Mitigation Planning Handbook from FEMA.

Preparation includes creating the individual clinic/facility evacuation plan itself. A big part of this is obtaining documentation beforehand—photos and video of all equipment and supplies, layout of the building, copies of assets and paperwork for safekeeping in a safe deposit box and electronically in a cloud format; arranging appropriate insurance.

Make sure your insurance coverage addresses the following:

● Business interruption (continuing expenses)—find out exactly when it ends, and what triggers the end.

● Extra expense (payment of overtime pay and relocation expenses).

● Professional extension (provides coverage for injury/loss/death of animal in a practice’s care).

● Custody or control. Normal professional liability only provides coverage during a case of treatment).

● Loss of income.

● Large animal and equine practitioners should consider “mobile loss of income” (which provides coverage in case a piece of equipment or vehicle cannot be used).

● Personal property (replacement value).

● Automatic inflation.

● Fire damage (typically included in business packages).

● Water damage (not typically covered in business packages—make sure you have flood insurance if you are in a flood zone).

● Debris removal/cleanup.

● Civil ordinance coverage (provides coverage in case the practice is unable to function because of an act of government).

● Comprehensive building and structure replacement.

● Coverage of rented and leased equipment.

● Interruption of power, heating/air, and sewer.

● Coverage of worker’s compensation.

● General and professional liability.

● Backing up computer records on the cloud with copies of identification, registration papers,
and photographs for each personally owned animal and any treatment or boarded animals.

Response is actionable measures when the affected area is under a watch-and-warning (danger is imminent) phases when responsible facility owners or managers implement their plans as appropriate. Even the best plan will not cover everything, so practitioners must be flexible, innovative, and address problems as the situation changes (Fig. 7). During the North California 49er fires in 1988, a large-scale evacuation of a variety of livestock, horses, llamas, and other animals including pets was conducted. Local emergent volunteers were highlighted as the single greatest factor in the success of the evacuation of animals to safety, and their efforts were most effective during the voluntary evacuation period, when it was safest for both humans and animals to be conducting movement.⁷

There are response actions that veterinarians can encourage their clients to follow based on local emergency management plans and guidance.¹² The recovery period is the time when local areas conduct cleanup after the emergency/disaster, which may last from a few days to months or longer. This will include immediate repairs to fencing, buildings and equipment, clearing debris, plans and preparation for rebuilding if destruction occurred, re-evaluating future needs based on facility/structural and animal losses, disaster applications, insurance claims, and official damage assessments. Any prior documentation will help prove losses to insurance companies and disaster specialists working a case.

Development of an “all-hazards” disaster plan allows response in a proactive manner to hazards that may occur. In the past, emergency management planned for separate incident types, (e.g., blizzard snow plans separate from flooding, high-wind events, or electricity loss plans) but experience has shown that all require similar preparation. The “all-hazards” approach means that in general, one basic solid plan can be applied to many other less common scenarios, helping to focus staff and client reactions to new dangers as the situation changes (such as the hurricane winds subside to flooding and tornados). By basing your plan on selected hazards with the greatest possibility of affecting your locale, you can build the plan based on appropriate responses of staff to planned concerns—all other planning then builds upon the basic plan. This saves time, money, and effort.

Imagination (and perhaps money) is the only limit to human planning for disasters. Although geography and climate will increase the possibility of certain scenarios (these might include barn fires and wildfires, blizzards, flooding, power loss, earthquake and mudslides, chemical spill contamination, high-wind events of tornado, hail storms, or hurricanes), many of these can be mitigated with proper planning and prevention.

There are three methods for development of disaster plans.

Best Planning in the absence of an immediate threat is the preferred but rarest method, because it provides everyone time to think through the plan and identify resources. Unfortunately, many people are too busy to devote the resources and time to plan, or take the attitude that it will never happen.

Good Another common method for planning is in the immediacy right before an impending disaster. Since
the public masses are using the same method, re-
resources are scarce and difficult to find (generators,
fresh water, fuel, food, and shelters).

Poor Planning during the actual disaster is a desperately
necessary but biased method that is followed by a
large contingent of the public, as seen in the after-
math of media-covered disasters. The real heroes
are not the people seen in media stories leading
their animals through the flood, wildfire smoke, or
getting on the road to evacuate; the true heroes are
the unsung ones that left days before or defend their
facilities with wise choices of location, shelter, and
preparation to help their clients.

Unfortunately, when people wait to use the last
two methods, some pay for their folly with their
lives, or the lives of their animals. An inventory of
the disaster types that are theoretically or statisti-
cally more likely to happen in their local area will
give the planner a place to start for both evacuation
plans, and shelter in place plans, and build success
in the face of disaster (Fig. 8).

Fitting into the Emergency Management Plan for your
Community

Online training materials to further apprise practi-
tioners and clinic owners/managers of planning
considerations for animals are available via online
FEMA courses:

- IS-10 Animals in Disaster, Module A: Awareness and Preparedness.
- IS-11 Animals in Disaster, Module B: Community Planning.
- IS-111 Livestock in Disasters.

These courses are basic to individual facility and
community awareness planning for emergencies
and disasters—available at http://training.fema.gov/
IS/FEMA—also provides the Professional Develop-
ment Series of independent study courses that
provide a well-rounded set of fundamentals for
those involved in local emergency management
or functioning as responders under the Incident
Command System (ICS). ICS 100 is mandatory
training for all federal, state, and local govern-
ment employees, and is free at http://training.
fema.gov/IS/.

4. Discussion
Where to Start with the Plan

The planning cycle starts with a recommendation
that the facility owner and staff conduct a hazard-
specific identification, a risk and vulnerability as-
essment, plus a capability and resource assessment
for their facility. The process is not complicated
and starts with thinking through the process and
writing plans down, then updating it as needed.
Having a written plan will help during chaotic times
when thought processes may not be clear. Plan-
ing efforts allow personnel the luxury of time and
resources to make informed decisions as to what
they want the appropriate courses of action to be, for
the respective hazard. Hazard-specific identifica-
tion is the process of evaluating the possibility of
hazards that have 1) a reasonable expectation of
occurring, and 2) could impact your facility based on
local geography, terrain, urbanization, and climate.
An official assessment for your area is available by

Fig. 8. Firefighter attempting to evacuate a horse from a stall under simulated wildfire conditions of fake smoke and under duress
of time. This type of evacuation practice demonstrates the challenges and gaps in an evacuation plan. Photo courtesy of Jack
Wilson.
might be protection of the electrical for specialty cooling and freezing assets for genetic material. In a treatment clinic, it might be refrigerators for maintaining drugs at the correct temperature, and preventing mold and mildew in feed. Capabilities may change based on training and resources in your area, but are there specific vulnerabilities in your facility that are necessary to preserve the welfare and quality of life for animals or fulfill important disaster recovery functions?

What best practices for your business do you use every day that increase your flexibility and ability to respond in disaster situations? Good examples of DAILY MANAGEMENT ROUTINES that increase business efficiency and safety, but double as preparation for disaster and emergency response are below:

- Basic fire safety ideas for human facilities should be applied to large-animal facilities. For example, ensure clear escape routes (you won’t find aisles in a human hospital littered with obstacles and “stuff”). Don’t allow shipments of hay, farm equipment, nonworking doors, or bedding piles, to block these paths. Escape routes should be available to leave the facility every 50 feet according to NFPA 150 Standards on Life and Fire Safety for Animal Housing and there should be a door to every stall on the outside wall as well as the inside aisle.

- Provision of veterinary health maintenance (vaccination, deworming, current Coggins test) is important for all animals in your care or management, and reduces stress in animals comingle with others at treatment clinics and public events, as well as in the event of emergency evacuation or sheltering. Every hurricane watch causes a rush for Coggins testing in Southeast states as owners try to get their vaccinations, health certificates, and Coggins tests updated; even though it is documented that vaccine efficacy takes weeks to build up immunity.

- Detailed biosecurity procedures for handling sick horses, healthy horses, and preventing transmission of disease in equine hospitals.

- Permanent identification of all animals is a crucial mitigation step to implement via freeze branding, tattoo, or microchipping. Temporary and visible methods can then be added prior to the disaster or during response as necessary. Numerous disasters have shown that animals with permanent ID have the best chance of being returned to their owners, and preventing theft. Disasters are one of the few times that clinic owners and clients can easily lose track of their horses (other reasons include escape and theft). Animals reunited with owners are usually from homes with responsible owners that initiate efforts to find
them, and their animals are identified. There are very few cases where horses are abandoned or stray animals, as an example, in Louisiana after hurricane Katrina, due to microchipping requirements of horses, only three horses didn’t get placed back to their original owners. Implement a NO SMOKING and NO ALCOHOLIC BEVERAGES policy within 250 feet of the barn.

Learn appropriate procedures to document neglect and abuse situations. Disasters may liberate animals living in horrific neglect, starvation, and abuse conditions prior to the disaster. Practitioners performing field rescues or providing care at a clinic or public animal shelter should carefully document these animals when examination points to neglectful pre-disaster conditions. Steps to take to document starvation/neglect/cruelty/abuse cases is not the focus of this paper, but should include law enforcement to allow prosecution of owners involved in illegal activities.

Maintain animal-owner contact information as part of the medical/boarding records, and have the owner sign a waiver delineating the plans so they understand how you will handle evacuation of their animals in an emergency where they may not be able to be contacted.

Safety meetings monthly/quarterly are an excellent way to get your staff involved in preventing injuries, problems with maintenance, and issues with handling or procedural safety. If management cares enough to take these comments seriously and makes proposed changes, it will encourage staff to care and be proactive in protecting your business and client horses.

Learn how to teach all horses under your care to load safely into trailers. Loading/unloading is the most dangerous task a horse learns, it is also dangerous to your staff unless done correctly. Set employees up for success in horsemanship, handling, and trailer loading as part of their education at your clinic. After all, horses left behind in evacuations of all types are often because the owner was unable to catch and transport it. Encourage clients to teach horses to load into a trailer at any time, under all conditions (e.g., at night, alone, raining, windy, dark, and generally miserable). It may save their life.

Shelter in Place

- Identify the shelter-in-place plan for horses in your region (for example, in South Florida, this is the only option left if you wait until 3 days ahead of a hurricane threat due to severe traffic congestion on escape routes. In California, some canyons are one way out only and require serious FireWise preplanning with CALFIRE to be able to defend your property in cases of evacuation orders (Fig. 10).

- Make evacuation escape plans in consideration of what the local Emergency Management plan and others are doing, so that your resources are available as outlined in your plan (i.e., Public sheltering for horses and pets filled fast in the Hurricane Irma evacuation from Florida all the way into Georgia, Louisiana, North Carolina, Virginia, South Carolina, Tennessee, Texas, Alabama, and Mississippi; however, private sheltering was still available if coordinated ahead of time).

- Identify safe areas for grazing (do not allow animals access to the hazardous materials found in floodwaters, volcanic ash, other chemicals, and fertilizer).

- Remove interior fencing so animals can reach higher ground if floodwaters are expected to rise or if the lower-priority animals have to be left behind in an unplanned disaster. Letting horses out of fencing to fend for themselves in wildfire or flooding is not recommended—they can be hit by cars, get trapped in various obstacles, or go for days with no water and feed.

- Leave ‘em in or leave ‘em out? In general, unless the disaster is electrical or chemical in nature, leave them out in the largest, best-built fenced pasture available. Horses will find cover in trees or natural shelter, and normally will stand with their hindquarters to the wind so that the muscles of the hindquarter will absorb any serious injury from flying debris, etc.—these injuries will look horrific but heal well. Horses can be electrocuted by falling power lines or lightning, crushed by flying vehicles and equipment, or lacerated by debris that now is dumped in their pasture. Alternatively, horses trapped in barns are subject to flying debris all around them and the high possibility...
of a building fire or collapse. After Hurricane Katrina in 2005, responders noted that they did not see a single barn still standing, and those that were left were destroyed (Fig. 11).f

Issues to address in planning include the following:

Prioritize the animals to be evacuated. Prioritize the value (actual market value or sentimental) of all animals annually and make a list of which animals to save first. This may sound harsh, but it is practical based on the hard lessons of previous disasters. A beloved 25-year-old lesson horse may be more valuable than the 4-year-old panicky show horse, and may be easier to evacuate as well. Identify which animals are easiest to load. Which seem to colic when they drink different water or hay? How many trailer spaces are available in the fleet? After packing that four-horse gooseneck trailer with four horses, is there room for dogs, cats, and human family or staff members? Would it take a second trip to retrieve other animals? In reality, disaster evacuation policy prevents return—once out with the first load, it is difficult to impossible to return for a second load.

Large numbers of animals should be evacuated very early in the case of wildfires, flooding, and hurricanes. It may require a great deal of labor, fuel, and other resources to move large numbers of animals. Maintaining a list of response partners (including neighbors, peers, colleagues, local officials) with the capability of assisting with moving animals and people out of harm's way is critical. Consult your emergency management and watch the weather channels to determine the extent of the disaster—get well out of the expected path. Stranded owners with their animals in the middle of a flood are unreachable to the outside world and on their own until assistance can arrive.

It is important to identify a sheltering location or evacuation site to move to. Options may include a humane sheltering facility for large animals, private farm, or public evacuation stable. What is the distance to the evacuation location? Establish prior coordination and maintain communications so that when the animals arrive the alternate facility has space. An example of a functional and regularly used plan is a Florida veterinarian who includes an evacuation plan for all interested clients. A horse trailer/van is automatically scheduled for prestorm evacuation ahead of the hurricane force winds reaching the coast. Horses are moved to a large harness facility in Hawkinsville, Georgia. The owners of the horses are then freed to pack their families, and follow their animals north out of harm's way. The owners share the cost of the large van, since many of the clients do not have enough trailer space for all their horses. This plan has been enacted three times in the last 20 years.g

Practice and Mock Drill of the Plan
See plan examples at the following links:

Fig. 11. Storm surge from Hurricane Katrina (2005) destroyed this stable and rescuers were unable to access the area for over 2 weeks after the disaster. Photo courtesy of Rebecca McConnico.
Evacuation Practice

The best way to prepare for evacuation is to do a mock evacuation drill— with everything you would want to take with you. Preparation can take hours (hitching trailers, fueling trucks, loading equipment and feed). Well ahead of the disaster onslaught, store several days’ supply of feed, water, medications, etc. as needed for each animal being evacuated or sheltered in place. Both human and animal first aid kits should be included with projected supplies (in a go-bag).

Prepare a checklist of specific tasks (includes clinic/farm/ranch/home) for evacuation or shelter in place that includes turning off the power, unplugging appliances, moving important documents to safe keeping (i.e., electronic records) and informing neighbors of your evacuation and other disaster plans.

Sheltering facilities should be identified within an appropriate radius of home (close by in the event of a single building fire; across town if only affecting a small specific area, further away for catastrophic or possible long-lasting effects such as hurricane, wildfire, or earthquake). Evacuees should expect to pay PER DAY, PER ANIMAL fees for evacuation facilities, campgrounds, or private facilities. Public facilities fill quickly with those who failed to plan, and may not provide the amenities expected for your horses.

Practice the evacuation plan you have developed by holding unannounced drills every 6 months for an evacuation of different scenarios (e.g., fire, flood, wildfire, volcano eruption, hail, hurricane, etc.). Vary the time of day (or night) and the requirements of the drill—does everyone really have to load up every horse in a trailer and haul it somewhere? Or could staff practice catching all horses and bringing them inside the treatment barn for a simulated hail storm? Could you place a stuffed animal in each stall and have personnel practice the steps required to ID, catch, load, and evacuate with 3 days’ worth of feed and medications to treat the animals—and just drive a few miles to the local stockyards for practice?

Practicing a plan is similar to childhood tornado drills in schools, with the emphasis on staying calm, thinking through the problems, and responding in a proactive manner, which will benefit human and animal resilience during emergencies. Think through to coordinate where to move evacuated animals in the event of emergency evacuations, especially as conditions change (wind direction, hurricane impact zones, precipitation estimates, etc.). Clients will expect your business to be resilient so that you can respond to their calls for help for animals injured or affected by the disaster (Fig. 12).

Communicate information about safe evacuation routes before the disaster, identify more than one safe route out of the neighborhood, remembering that the officials may block at least one route under the emergency, and traffic may affect the other. Set up a phone/text messaging tree to communicate the practice’s emergency plans and response information with clients (e.g., where to bring injured or affected animals for necessary treatment, availability of services after the disaster passes, etc.). In many past disasters, Internet and cell phone communications has been unavailable for hours to weeks—communication plans should include nondigital methods. Recommended communication resources include a NOAA weather radio (battery powered), two-way radio, push-to-talk/text/audio phone, Internet access (tablet, etc.), and a CB radio.

Updates to your social media, Web site, and phone messaging should make it easy for clients to find and receive up to date information. The challenges with social media should be considered in your plan—if you are not able to provide services, make it known. Emphasize partnerships in practices across town, across the state, and out of state—so that your business maintains continuity as part of your long-term emergency planning.

Risk identification, reduction, and mitigation of the effects of disaster on the practitioner’s business and family starts with a well-written plan taking an all-hazards approach to sheltering in place, and/or evacuation as crucial parts of effective equine facility management. By setting the example in their communities, practitioners will gain personal experience that reaches into other areas of their lives.
and make them better able to advise their clients. The goal is to increase the resiliency of the entire agricultural community by integrating animal issues into an overall emergency management strategy for the community, state, and nation.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References and Footnotes


a Mansmann, R. Spring Lake, NC. (personal communication) 2005.
b Culver, A. Alexandria, VA. (personal communication) 2006.
c Bevan, L. Tallahassee, FL. (personal communication) 2006.
d Marquette B. Ruston, LA. (personal communication) 2005.
e Schwartz A. Lisbon, MD. (personal communication) 2006.
f Gimenez T. Pendleton, SC. (personal communication) 2005.
g Merrick C. Daytona, FL. (personal communication) 2016.
Straight from the Heart: Untangling the Complexities of the Equine Cardiovascular System

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1. Introduction
The heart is integral to the prowess of the horse as a superb athlete. Horses during peak performance are able to increase their cardiac output 8–12 times over their resting values, primarily through an increase in heart rate. Their heart rate increases 6–8-fold over their resting rate to a maximum of 220–240 beats/minute (bpm) or more during exercise, which, combined with their increased stroke volume (approximately 1.75-fold), results in their marked increase in cardiac output during peak exercise. Together with the lungs, the cardiopulmonary system is the most important determinant of a horse’s performance ability. Horses increase their oxygen consumption during maximal exercise 40-fold over their resting state through their large lung capacity, a well-functioning upper and lower airway, excellent oxygen-carrying capacity, extensive capillary network, and the superbly designed and functioning heart.

Numerous technological advancements over the past five decades have vastly improved our understanding of the equine cardiovascular system in health and disease. Knowledge of the severity of a wide variety of equine cardiac conditions has enabled clinicians specializing in equine cardiology to assess the significance of arrhythmias and murmurs and predict their impact on a horse’s performance, career, and life expectancy.

2. Auscultation
Careful auscultation of both sides of the thorax is essential. All four heart sounds are often audible, although they are heard best over different areas of the cardiac silhouette. The fourth heart sound (S4) is usually heard best over the heart base, is a late diastolic sound preceding the first heart sound (S1), and is usually softer than the first or second heart sound (S2). S1 is the loudest heart sound, occurring at the onset of systole, and is composed of the closure of the atrioventricular (AV) valves, the reverberation of blood in the ventricles, and the opening of the semilunar valves. The apex beat is simultaneous with S1. S2 is the next loudest heart sound, occurring at the end of systole and is composed of the closure of the atrioventricular (AV) valves, the recoil of blood in the great vessels, and opening of the AV valves. The second heart sound is usually heard best over the heart base. The third heart sound (S3) is associated with the end of the rapid ventricular filling phase. S3 is an early diastolic
sound that is usually softer than S1 or S2 and is heard best over the cardiac apex. The resting heart rate is usually between 24–44 bpm, but higher heart rates are present in horses that are anxious or excited at rest. Higher heart rates may also be found in foals, yearlings, and draft horses.

Rhythm
Although a regular sinus rhythm is most common in horses, second degree AV block (2°AVB) is a very common arrhythmia, occurring in 44% of horses during a continuous 24-hour electrocardiogram (ECG)1 and detected in 15–18% of horses on a routine ECG.2,3 Sinus arrhythmia occurs with 2°AVB but also occurs alone and is a normal vagally mediated arrhythmia in horses at rest. Sinus bradycardia, sinoatrial block, and sinoatrial arrest are also normal vagally mediated arrhythmias in resting horses, but are uncommon. All vagally mediated arrhythmias should be detected in relaxed or fit horses at rest, be detected with low normal heart rates, and should disappear with exercise or excitement.

Murmurs
A cardiac murmur is an audible sound that occurs associated with the vibration of blood in the heart or great vessels during a normally quiet period of the cardiac cycle. Murmurs are described by their intensity, timing, duration, quality (pitch or frequency), shape, point of maximal intensity (PMI), and radiation. The timing of the murmur refers to the phase of the cardiac cycle during which the murmur is detected (systolic, diastolic, or continuous). The duration of the murmur is the length of time during the phase of the cardiac cycle that the murmur is detected (early, mid, late, holosystolic, or pansystolic). The quality of the murmur refers to the frequency or pitch of the murmur, described as blowing, musical, buzzing, honking, “dive bomber,” or machinery (washing machine). The shape of the murmur refers to the auscultatory and phonocardiographic shape of the different murmurs frequencies, described as band shaped or plateau, crescendo, decrescendo, or crescendo-decrescendo. The PMI refers to the valve area or location on the thorax where the murmur is the loudest, and the radiation refers to the direction to which the sound is transmitted. Murmurs are usually loudest in the direction of the abnormal (turbulent) blood flow.

Murmur intensity is most frequently graded on a 1–6 scale.

Grade 1/6: The quietest murmur, one that is very localized and only heard after minutes of intense listening.

Grade 2/6: A soft murmur that is heard immediately when the stethoscope is over the PMI but which is softer than S1 or S2, is localized, and does not radiate.

Grade 3/6: A louder murmur that is heard immediately, is louder than S1 or S2, and is less localized.

Grade 4/6: A louder murmur that is heard immediately, radiates widely, and may have a faint precordial thrill.

Grade 5/6: A very loud murmur that is heard immediately, radiates widely, and has a prominent precordial thrill.

Grade 6/6: The loudest murmur that can be heard with the stethoscope, even when removed slightly from the chest wall. This murmur radiates widely and has a very prominent precordial thrill.

Physiological Flow Murmurs
Soft, early to mid, or holosystolic ejection murmurs are commonly present over the aortic and pulmonic valve areas. These ejection murmurs are physiologic and are associated with ejection of blood out the great vessels. Early or late diastolic murmurs are also typically physiologic and not associated with any cardiac pathology.4,5 Flat racing Thoroughbreds and National Hunt horses have a high prevalence of left-sided systolic murmurs (53%), left-sided early diastolic murmurs (22%), and right-sided early diastolic murmurs (23%) consistent with physiological flow murmurs.4 Classical physiological flow murmurs have been described as increasing in intensity with an increased heart rate, but significant systolic murmurs also increase in intensity with a heart rate increase.6 Therefore, the detection of an increase in murmur intensity with an increased heart rate is not a suitable means for differentiating physiological murmurs from murmurs associated with underlying cardiac disease.6

Murmurs Associated with Cardiac Pathology
Murmurs associated with cardiac pathology are usually louder (greater than or equal to a grade 3/6), heard throughout systole and diastole, or, less frequently, continuously, are coarse in quality or musical and radiate somewhat from their PMI. However, there are exceptions to this rule. In the adult horse, murmurs rarely radiate to the opposite side of the thorax unless they are loud and musical in quality. Any grade 3/6 holosystolic or pansystolic murmur with its PMI on the left side of the thorax is mitral regurgitation (MR) until proven otherwise. Any holodiastolic murmur, regardless of its intensity is aortic regurgitation (AR) until proven otherwise. With the advent of echocardiography and, in particular, pulsed-wave, continuous-wave, and color-flow Doppler echocardiography, the differentiation of physiologic murmurs from those associated with underlying cardiac pathology can be readily made.

3. Diagnostic Tests Used for Evaluation of Horses with Cardiac Disease
Electrocardiography and echocardiography form the backbone of the diagnostic tests used to evaluate horses with cardiac disease. Cardiac troponin I (cTnI) or T (cTnT) are the preferred tests to use to look for myocardial damage.
Electrocardiography

ECGs have been used to evaluate the horse’s cardiac rhythm for decades. Significant advances in technology have occurred over the last couple of decades, enabling high-quality ECGs to be obtained in a wide variety of circumstances. This has resulted in significant increases in our knowledge of normal and abnormal cardiac rhythm in horses. Transient ECGs can be obtained readily with a hand-held smartphone-enabled recording device, enabling the equine practitioner to obtain a recording of the horse’s heart rhythm in the moment (Fig. 1), documenting the rhythm for a period of 30 seconds. Continuous ECGs can be obtained using a digital Holter monitor (Fig. 2), yielding information about the horse’s heart rhythm during a lengthy monitoring period of 24 hours (most common) or longer (up to 7 days). The continuous ECG recordings can be synchronized with video recordings, enabling the clinician to correlate abnormal behavior or episodes of collapse or near collapse with the horse’s cardiac rhythm. Real-time monitoring of the equine ECG using telemetry (Fig. 3) can be performed, not only at rest or during treatment, but high-quality recordings can also be obtained during exercise.

Echocardiography

In the early days of equine echocardiography (1970s), only blind motion-mode (M-mode) echocardiography was available. Pattern recognition was critical to obtaining these images, as two-dimensional (2D) echocardiography was not yet available to use as a template from which M-mode images could be obtained. The cardiac window was identified in the right fourth intercostal space approximately midway between the level of the point of the shoulder and the point of the elbow. Transducer manipulations were developed to obtain standard M-mode echocardiographic images of the left ventricle, mitral valve, and aortic valve over time. These early studies described the normal findings with blind M-mode echocardiography in clinically normal horses, horses with bacterial endocarditis, and horses with congenital defects by using contrast echocardiography. Then, 2D echocardiography became a reality, resulting in an increasing body of knowledge about what is normal in a wide variety of breeds and ages of horses and ponies, as well as descriptions of a variety of cardiac pathologies.

Pulsed- and continuous-wave Doppler echocardiography were developed in the absence of simultaneous 2D echocardiography. Pulsed-wave Doppler echocardiography enables turbulent flow to be precisely located within the heart or great vessels, but high peak velocities cannot be resolved. Continuous-wave Doppler echocardiography allows for accurate measurement of very high velocities and the identification of the flow direction; however, precise localization of flow is not possible. With continuous-wave Doppler echocardiography, ultrasound is
continuously emitted and received from the transducer along a straight line. The signal displayed reflects all flow occurring anywhere along that line. Color-flow Doppler echocardiography is a form of pulsed-wave Doppler echocardiography where the color Doppler information is superimposed upon the 2D echocardiographic image, enabling blood flow to be displayed on this image in real time. With color-flow Doppler echocardiography, blood flow toward the transducer is typically displayed in red and flow going away from the transducer in blue. High-velocity turbulent flow is displayed in different colors, enabling detection of regurgitant jets, shunts, and turbulence associated with a stenotic lesion. This body of knowledge in M-mode, 2D, and color-flow Doppler echocardiography is the mainstay of the equine echocardiographic evaluation today.

Color-flow Doppler echocardiography is a sensitive technique, and small amounts of regurgitant flow consistent with trace or clinically insignificant regurgitation are commonly detected in horses without a heart murmur. These small jets may not consistently be detected on repeated examination, which may be related to hemodynamics, compliance, valve factors, jet direction, and the technical issues associated with the echocardiographic examination. More recently, evaluation of myocardial wall motion with tissue Doppler imaging (TDI) and 2D speckle tracking (2DST) is resulting in new knowledge about myocardial function that will continue to expand.

Four-dimensional (4D) echocardiography has relatively recently been adapted to the horse, yielding three-dimensional (3D) images of the heart over time. These 4D images can enhance the visualization of congenital cardiac defects and valvular pathologies, particularly valvular endocarditis. Optimized 4D echocardiography has confirmed aortic valve prolapse (AVP) in the horse, documenting what was detected with routine 2D echocardiography. 4D echocardiography also presents exciting possibilities for more critical assessments of left ventricular systole and diastole volumes.

Echocardiographic examinations should be performed, whenever possible, with the horse relaxed and unsedated. When this is not possible, acepromazine is the sedative of choice, administered early so that it is most effective. Acepromazine is preferable to the α-adrenergic drugs because the latter affect numerous echocardiographic measurements and significantly depress myocardial contractility. However, acepromazine has been shown to decrease the left atrial diameter in normal horses, which should be kept in mind when evaluating horses with MR.

4. Evaluation of Heart Murmurs with Emphasis on Diagnosis, Severity, and Impact on Performance, Life Expectancy, and Horse and Rider Safety

Physiological flow murmurs are frequently detected in horses. The most common acquired murmurs are associated with regurgitation of the tricuspid,
mitral, and aortic valves, while the most common congenital heart murmurs are those heard in a horse with a ventricular septal defect (VSD). Many horses have more than one murmur and only 18.9% of a large population of Thoroughbred racehorses lacked an auscultable murmur.6 Murmurs of tricuspid regurgitation (TR), MR, and AR have been reported in up to 16.4%, 5.6% and 3.1% of horses, respectively.4,6 Many racehorses with heart murmurs have normal cardiac size and function. The echocardiographic evaluation is critical for assessing the severity of the valvular regurgitation present or the hemodynamic significance of a VSD. These findings can then help determine the impact of this cardiovascular abnormality on the horse’s performance, life expectancy, and the safety of using the horse for its intended discipline. An echocardiographic examination should be performed when there is a grade 3/6 or louder holo-or pansystolic murmur or a holodiastolic decrescendo murmur detected.

Mitral Regurgitation
MR is common in horses and is frequently associated with a normal performance life and life expectancy. MR accounted for 35% of horses presented to one referral clinic; 50% of these had a history of poor performance.33 Murmurs of MR have been shown to increase in intensity and prevalence in young Standardbred racehorses4,34 and Thoroughbred flat racehorses with training.35 An MR murmur has been reported in 9% of geriatric horses in the United Kingdom.36 The prevalence of MR is highest in horses racing over fences in the United Kingdom (23% of steeplechasers).37

Any loud systolic murmur detected on the left side of a horse’s chest should be considered to be MR until proven otherwise. The murmur of MR is typically loudest in the mitral to aortic valve area, radiating dorsally, dorsocranially, or dorsocaudally.30,38,39 There are three types of MR murmurs that are associated with different mitral valve abnormalities.30,39 The murmur of mitral valve prolapse (MVP) is typically a crescendo mid to late systolic murmur, although the murmur may be holosystolic and loudest in mid to late systole.30,40 A holosystolic or pansystolic plateau or band-shaped murmur is typical of degenerative valve disease but may also occur secondary to mitral annular dilatation. The characteristic murmur detected in horses with a ruptured chordae tendineae (RCT) is a musical honking murmur.30 Although the louder murmurs may be associated with more significant regurgitation, no significant association has been made between the intensity of the murmur and the severity of the regurgitation.

Horses with mild MR are competing successfully in all types of equestrian sports. These horses have no significant change in pulmonary artery wedge pressure when compared with normal horses during exercise, suggesting that the MR is not hemodynamically significant.41 As the MR increases in severity, significant increases in pulmonary artery wedge pressure occur in some horses with moderate MR and this has the potential to affect performance.41

Echocardiographic Findings
Abnormalities of the mitral valve leaflets are frequently detected echocardiographically and are important in determining the underlying pathology and, ultimately, the horse’s prognosis.

Degenerative valve disease is common, usually imaged as diffuse thickening of the valve leaflets; however, nodular thickening may be detected.38 Although increased echogenicity and thickening of the free edge of the leaflet can be detected echocardiographically, it is a somewhat subjective finding.

Prolapse is also a commonly detected echocardiographic finding, whereas a thickened or RCT, flail leaflet, or endocarditis lesion are less so.38 Mitral valve dysplasia is also uncommon.46,47 The mitral valve leaflets should be evaluated in long and short axis from both the right and left parasternal windows. Bulging of the affected leaflet back into the left atrium during mid to late systole or throughout systole, worst in mid to late systole, is consistent with MVP (Fig. 4).12,30,39 Care needs to be taken in making this diagnosis due to the saddle shape of the mitral annulus, but the detection of a jet of MR adjacent to the area of prolapse with the characteristic murmur is consistent with the diagnosis (Fig. 5).39 The first report of MVP in the horse described sagging of the free wall leaflet during systole imaged with M-mode echocardiography.38 An RCT is diagnosed when a chordae tendineae is imaged evertting into the left atrium in systole (Fig. 6).38,44,48 Although RCT are often associated with degenerative
valve disease, they also occur associated with bacterial endocarditis. RCT have also been reported in foals. A leaflet or portion thereof that is moving asynchronously with the rest of the valve during the cardiac cycle is consistent with a flail leaflet (Fig. 7; Flail Mitral Valve Movie). An irregularly shaped hypoechoic to echoic mass on the mitral valve leaflet or chordal structures is consistent with an endocarditis lesion.

As the MR worsens, left atrial enlargement ensues (Fig. 8; Severe MR with AF Movie), followed by left ventricular enlargement and rounding of the apex. With left ventricular volume overload there is increased systolic thickening of the interventricular septum and left ventricular free wall, resulting in an increased fractional shortening. As the regurgitation worsens, thinning of the interventricular septum and left ventricular free wall occur and left ventricular dysfunction appears. A decreased fractional shortening in the face of an enlarged left ventricular internal diameter at the end of diastole is an indication of left ventricular dysfunction.

Color-flow Doppler echocardiography reveals the jet(s) of MR, originating between the leaflets, most frequently from the coaptation of the cranial or caudal accessory leaflets with the septal and free wall leaflets of the mitral valve. The MR jet often extends toward the base of the left atrium as a plume (Fig. 9; Large MR Jet Movie), although it may also be directed toward the left atrial free wall or interatrial septum. In some horses, the size of the MR jet is more difficult to assess as the jet flattens out along the atrial side of the valve leaflets, rather than ex-

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**Fig. 5.** Color-flow Doppler echocardiogram of the jets associated with MVP visualized in the right parasternal long axis four-chamber view. Notice the two forked jets of MR (arrows) originating on either side of the prolapsing portion of the mitral valve. RV, right ventricle; LA, left atrium; LV, left ventricle. The V at the top right of the image indicates the orientation of the transducer which is dorsal in this image.

**Fig. 6.** RCT of the caudal accessory leaflet of the mitral valve. Notice also the rhythm of AF on the simultaneous ECG. LA, left atrium; LV, left ventricle. A, The RCT is imaged everting into the left atrium in systole (arrow). This is a left parasternal long axis view of the mitral valve. The V at the top right of the image indicates the orientation of the transducer which is dorsal in this image. B, Postmortem image of the RCT (arrow) of the caudal accessory leaflet of the mitral valve (CDAL).

**Fig. 7.** Flail caudal accessory leaflet of the mitral valve (arrow) that is imaged moving asynchronously from the other mitral valve leaflets. This leaflet is moving into the mitral annulus during diastole. This is a left parasternal short axis view of the mitral valve. CDAL, caudal accessory leaflet; FWL, free wall leaflet; S, septal leaflet; AO, aorta. The V at the top right of the image indicates the orientation of the transducer which is cranial in this image.

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**Fig. 9.** Large MR Jet Movie, showing the jet(s) of MR originating between the leaflets, most frequently from the coaptation of the cranial or caudal accessory leaflets with the septal and free wall leaflets of the mitral valve.
tending out into the chamber as a plume. Often, the jet of MR is much better visualized from one of the cardiac windows than the other, usually from the left parasternal window (Figs. 9 and 10). The size of the MR jet is graded as 1+ or trace, 2+ (mild), 3+ (moderate), or 4+ (severe). With 4+ MR, the jet usually extends more than two-thirds of the way toward the base of the left atrium. Acceleration of the jet on the ventricular side of the mitral valve, before it goes through the mitral orifice, is an indication of increasing severity of MR (Fig. 10). Continuous-wave Doppler echocardiography is used to obtain a spectral tracing of the MR jet, taking care to align the ultrasound beam as close to parallel with the regurgitant jet as possible. As the signal
intensity of the spectral Doppler tracing increases, the severity of the MR is also increasing (Fig. 11). With clinically insignificant MR, there is one or two very small jets (1+) of MR with a normal-sized left atrium. The left atrium is also normal size when the regurgitation is classified as mild MR, but in these horses, the jet of MR is larger (2+). The regurgitation is classified as moderate when left atrial enlargement is present, and there is a larger jet that extends one-third to two-thirds of the way back into the left atrium. With severe MR (unless it is acute), marked left atrial enlargement is present, often along with pulmonary hypertension. A dilated pulmonary artery or a TR velocity >3.5 m/s in a horse with left-sided heart disease is consistent with pulmonary hypertension.

**Significance/Prognosis**

MR associated with MVP is usually extremely well tolerated, with most horses having a normal performance life and life expectancy, unless there is a larger jet of MR and more left atrial and ventricular volume overload. MR has been reported in Thoroughbred racehorses (3.5%, 2.8%) that were performing up to expectations. MR was found in a similar percentage of Standardbred racehorses presenting for poor performance (3.1%), but in only one horse was the MR severe enough to account for the poor performance. This horse had a grade 3/6 MR murmur with a moderate-sized jet of MR, marked left atrial and left ventricular enlargement, left ventricular systolic dysfunction, and pulmonary edema detected on thoracic ultrasound. Mild MR has a good midterm prognosis in sport and pleasure horses, with only a small but statistically significant increase in left ventricular internal diameter at end diastole being detected over several years.

Although there is considerable variation in the arrangements of the chordae tendineae and the accessory (commissural) leaflets of the equine mitral valve, larger than normal accessory leaflets (usually cranial) with a smaller than normal free wall leaflet is detected in a number of horses with mild MR and is consistent with mild mitral valve dysplasia.

With left atrial enlargement and moderate to severe MR, the use of the angiotensin-converting enzyme (ACE) inhibitor benazepril is recommended to reduce afterload. A decrease in left ventricular internal diameter in systole and an increase in fractional shortening and cardiac output can be expected in horses treated for 4 weeks at 1 mg/kg orally (PO) twice daily.

As the MR worsens and the left atrial enlargement develops, atrial premature complexes (APCs) may be detected or AF may develop. When MR is severe, ventricular arrhythmias may also be detected; some affected horses had myocardial fibrosis or necrosis at postmortem examination. An unusually loud third heart sound is an indication of advancing MR severity; this sound increases in intensity with the high-velocity early diastolic flow and the development of left ventricular volume overload.

Determining the significance of the MR involves consideration of the character of the arterial pulses, lesions detected on the valve, changes in the cardiac chamber size and shape, myocardial function, changes in the pulmonary veins and pulmonary artery, Doppler indices of MR severity, and the arrhythmias detected at rest and during exercise, if any (Table 1). Although moderate to severe MR is associated with a shortened life expectancy when detected in a young horse, most horses with MR have a normal life expectancy. The rupture of a major chordae tendineae often results in the acute onset of left-sided congestive heart failure (CHF) and has been reported in young horses. There is, however, no shortening of life expectancy in middle-aged and older horses with left-sided valvular regurgitation compared with the general horse population.

**Tricuspid Regurgitation**

Murmurs of TR are a common finding in equine athletes. The prevalence of TR murmurs was high in National Hunt horses (16.5%) compared with Thoroughbred flat racing horses (4.8%) and competition/pleasure horses (3.2%) in one UK survey. However, another investigator found a similar prevalence of TR in Thoroughbred racehorses (21.8%). There are numerous studies that report the murmur of TR to both increase in severity and become more prevalent with training, suggesting that training is an important factor in the development of TR. TR murmurs have been reported in 5% of geriatric horses in the United Kingdom.

TR is also a common finding in horses with severe MR and pulmonary hypertension. Horses presenting with bilateral systolic murmurs usually have both MR and TR, with the primary valvular pathology being left sided; the TR is secondary to the pulmonary hypertension that develops. Horses with severe lower airway disease (cor pulmonale) may also develop TR secondary to the severe pulmonary disease. Although structural abnormalities of the valve do occur, they are much less frequent than on the mitral or aortic valve. Murmurs of TR are most typically soft and blowing, band shaped, holosystolic, and a grade 2–3/6. Murmurs of TR that are louder are associated with jets that are longer in duration and larger in area than that detected with softer TR murmurs.

**Echocardiographic Findings**

Abnormalities of the tricuspid valve leaflets are much less common than of the mitral or aortic valve.
Table 1. Prognostic Guidelines for Performance of Horses with Mitral Regurgitation, Aortic Regurgitation, and Ventricular Septal Defect§∗

### Mitral Regurgitation

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Fair</th>
<th>Guarded to Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial pulses</td>
<td>Normal</td>
<td>Normal or mild MVP</td>
<td>Weak</td>
</tr>
<tr>
<td>Valve lesion</td>
<td>None, mild MVP</td>
<td>Mild thickening, moderate MVP, mild to moderate dysplasia</td>
<td>Severe thickening, severe MVP, RCT, flail leaflet, endocarditis, severe dysplasia</td>
</tr>
<tr>
<td>LA enlargement</td>
<td>Absent or mild</td>
<td>Mild to moderate</td>
<td>Moderate to severe</td>
</tr>
<tr>
<td>LA shape</td>
<td>Normal</td>
<td>Normal or slightly rounded</td>
<td>Might appear round and turgid</td>
</tr>
<tr>
<td>Interatrial septum</td>
<td>Normal</td>
<td>Normal</td>
<td>Might be bulging towards RA</td>
</tr>
<tr>
<td>LV volume overload</td>
<td>Absent</td>
<td>Mild</td>
<td>Moderate to severe</td>
</tr>
<tr>
<td>LV systolic function</td>
<td>Normal</td>
<td>Normal</td>
<td>Hyperdynamic, normal (less than expected) or decreased</td>
</tr>
<tr>
<td>Pulmonary vein enlargement</td>
<td>Absent</td>
<td>Absent</td>
<td>Usually present</td>
</tr>
<tr>
<td>PA enlargement</td>
<td>Absent</td>
<td>One or more medium sized jets</td>
<td>Present or developing</td>
</tr>
<tr>
<td>MR jet**</td>
<td>One or multiple small &amp; narrow jets</td>
<td>Preexisting</td>
<td>Large single or large multiple jets</td>
</tr>
<tr>
<td>AF, APCs</td>
<td>Absent</td>
<td>Absent</td>
<td>Secondary</td>
</tr>
<tr>
<td>Ventricular arrhythmias</td>
<td>Absent</td>
<td>Absent</td>
<td>VPCs may be present</td>
</tr>
</tbody>
</table>

### Aortic Regurgitation

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Fair</th>
<th>Guarded to Poor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arterial pulses</td>
<td>Normal</td>
<td>Normal or slightly bounding</td>
<td>Bounding or weak</td>
</tr>
<tr>
<td>Arterial blood pressure</td>
<td>Normal</td>
<td>Nodular thickening, moderate AVP-suspected fenestration</td>
<td>Pulse pressure &gt;60 mmHg, Severe thickening or AVP, flail leaflet, endocarditis, congenital malformation</td>
</tr>
<tr>
<td>Valve lesion</td>
<td>None, parallel fibrous band, mild AVP</td>
<td>Mild decrease in diastolic diameter</td>
<td>Mild to severe enlargement; moderate or severe decrease in diastolic diameter</td>
</tr>
<tr>
<td>Aortic root</td>
<td>Normal</td>
<td>Normal or mild enlargement; mild decrease in diastolic diameter</td>
<td>Moderate to severe; Hyperdynamic or decreased</td>
</tr>
<tr>
<td>LV volume overload</td>
<td>Absent or mild</td>
<td>Mild to moderate</td>
<td>Moderate to severe</td>
</tr>
<tr>
<td>LV systolic function</td>
<td>Normal</td>
<td>Hyperdynamic</td>
<td>Hyperdynamic or decreased</td>
</tr>
<tr>
<td>AR jet**</td>
<td>One or two small and narrow jets</td>
<td>One or more medium sized jets</td>
<td>Large single or large multiple jets</td>
</tr>
<tr>
<td>Long pressure half-time***</td>
<td>Moderate pressure half-time***</td>
<td>Short pressure half-time***</td>
<td>Short pressure half-time***</td>
</tr>
<tr>
<td>LA enlargement</td>
<td>Absent</td>
<td>Absent or mild</td>
<td>Mild to severe</td>
</tr>
<tr>
<td>Concurent MR</td>
<td>Absent</td>
<td>Absent or preexisting</td>
<td>Secondary to AR</td>
</tr>
<tr>
<td>PA enlargement</td>
<td>Absent</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Ventricular arrhythmias</td>
<td>Absent</td>
<td>Absent</td>
<td>VPCs, VT may be present</td>
</tr>
<tr>
<td>AF</td>
<td>Absent</td>
<td>Preexisting</td>
<td>Secondary</td>
</tr>
<tr>
<td>Age at onset</td>
<td>Older</td>
<td>Middle age</td>
<td>Young</td>
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### Ventricular Septal Defect

<table>
<thead>
<tr>
<th></th>
<th>Excellent</th>
<th>Fair or Uncertain</th>
<th>Guarded to Poor</th>
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<tr>
<td>Arterial pulses</td>
<td>Normal</td>
<td>Normal</td>
<td>Bounding or weak</td>
</tr>
<tr>
<td>Size of VSD****</td>
<td>≤2.5 cm</td>
<td>&gt;2.5–3.5 cm</td>
<td>&gt;3.5 cm</td>
</tr>
<tr>
<td>Shunt velocity</td>
<td>&gt;4.5 m/s</td>
<td>3.0–4.5 m/s</td>
<td>&lt;3.0 m/s</td>
</tr>
<tr>
<td>Volume overload</td>
<td>Mild</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td>LV systolic function</td>
<td>Normal</td>
<td>Hyperdynamic</td>
<td>Hyperdynamic or decreased</td>
</tr>
<tr>
<td>Aortic valve bulges into VSD</td>
<td>Absent or small</td>
<td>Medium and restricting flow</td>
<td>Severe</td>
</tr>
<tr>
<td>Concurent AR</td>
<td>Absent</td>
<td>Moderate</td>
<td>Severe</td>
</tr>
<tr>
<td>Pulmonary artery enlargement</td>
<td>Absent or mild, systolic only</td>
<td>Moderate, systolic only</td>
<td>Severe, systolic, and diastolic</td>
</tr>
<tr>
<td>Right ventricular hypertrophy</td>
<td>Absent</td>
<td>Absent, mild</td>
<td>Present</td>
</tr>
<tr>
<td>Concurent MR</td>
<td>Absent</td>
<td>Absent</td>
<td>Moderate to severe</td>
</tr>
<tr>
<td>AF</td>
<td>Absent</td>
<td>Absent</td>
<td>Present</td>
</tr>
<tr>
<td>Complex congenital heart disease</td>
<td>Absent</td>
<td>Absent or mild</td>
<td>Present</td>
</tr>
</tbody>
</table>

§Adapted from the Joint ACVIM/EVEIM Consensus statement “Recommendations for Management of Equine Athletes with Cardiovascular Abnormalities.”

∗Combined assessments are essential in accurately formulating a prognosis for life and performance and should include lesions detected, size of cardiac chambers, myocardial function, color Doppler assessment of jet, Doppler (CW)/hemodynamic estimates, age at onset, and intended use of horse.

**Jet includes both the width of the regurgitant flow at the valve orifice (at the vena contracta) and the jet area relative to the receiving chamber area, in which case the “jet” likely includes entrained red blood cells. Width of the jet at the valve orifice is difficult to measure accurately due to dynamic, nonuniform, 3D structure at the vena contracta. Jet area is highly dependent on technical factors including ultrasound beam angle, transducer distance from the region of interest, transducer frequency, 2D and color gain and filter settings, pulse-repetition frequency, and image plane.

***Pressure half-time cannot be accurately measured unless the interrogating beam is maintained at a constant angle with the regurgitant jet.

****VSD diameter is for average 450–500 kg horse. VSD can change in size, be covered by aortic valve or tricuspid valve, is 3-dimensionally difficult to characterize and the edges may not be easy to measure.

LA, left atrial; LV, left ventricular; PA, pulmonary artery; MR, mitral regurgitation; AF, atrial fibrillation; MVP, mitral valve prolapse; AVP, aortic valve prolapse; RCT, ruptured chorda tendinea; RA, right atrium; APCs, atrial premature complexes; AR, aortic regurgitation; VPCs, ventricular premature complexes; VT, ventricular tachycardia; VSD, ventricular septal defect.
leaflet in horses with regurgitant murmurs. Prolapse, RCT, and flail leaflets of the tricuspid valve, when present, are similar in appearance to those same structural changes involving the mitral valve. Tricuspid valve dysplasia has been reported but is rare. Endocarditis lesions also occur on the tricuspid valve, most frequently associated with septic jugular vein thrombophlebitis. These lesions also appear similar to those seen on the mitral valve. Most horses in training with TR have a normal-sized right atrium and ventricle, with a small jet of TR directed toward the aortic root (Fig. 12). With more significant TR, right atrial and right ventricular enlargement are usually present with rounding of the right ventricular apex, and there may be abnormalities of the valve structure or leaflet motion, along with a larger jet of regurgitation. The jet of TR is then often directed centrally or toward the RA free wall or imaged in the four-chamber view in horses with moderate to severe TR (Fig. 13). Paradoxical septal motion is present when the TR becomes severe. There is a significant correlation between the severity of TR identified by color-flow Doppler echocardiography and the right ventricular internal diameter.

Significance/Prognosis

TR is extremely well tolerated. The majority of horses with murmurs of TR have normal right heart size and function. In most studies, there was no relationship between TR and poor performance. The right atrial enlargement present in horses with moderate or severe TR does increase the risk of AF, but this risk is less than with left atrial enlargement and moderate to severe MR. Only when TR is severe is it likely to affect performance and then usually only in upper-level horses. Life expectancy is usually only affected in horses with severe TR because it is secondary to severe left-sided heart disease.

Aortic Regurgitation

AR is a common finding in middle-aged to older horses, and is most typically associated with degenerative changes on the aortic valve. Male horses are more frequently affected. The prevalence of AR varies with age and with different equine populations. Up to 7.5% of geriatric horses and 7% of steeplechasers have been reported to have a murmur of AR. Most agree that the true prevalence of AR in older horses is probably higher. Murmurs of AR, although detected in young racehorses, are much less prevalent than TR or even MR. The prevalence of AR in Thoroughbred racehorses was 2.2% and was no different in Standardbred racehorses presenting for poor performance (1.2%). AR, although uncommon, does increase in prevalence with training in Standardbred racehorses. One young Thoroughbred racehorse also developed AR after 9 months of training. Physiological AR is commonly detected with color-flow Doppler echocardiography in the absence of a diastolic murmur.

The murmur of AR is holodiastolic, decrescendo and can be soft and blowing or loud and musical, often with a dive bomber quality. Late diastolic accentuation of the murmur can occur. The PMI of the murmur is at the aortic valve area, with the murmur radiating toward the cardiac apex. Any holodiastolic decrescendo murmur detected on the left side of a horse’s chest should be considered AR until proven otherwise. The murmur is typically heard over the right cardiac silhouette as a less
intense murmur but of similar quality. The intensity of the murmur of AR does not correlate well with its severity, especially when the murmur is loud, musical, and dive bomber in quality. However, the detection of hyperkinetic or bounding arterial pulses is an indication of a widened pulse pressure, left ventricular volume overload, and significant AR. As AR increases in severity, diastolic pressure falls and systolic pressure rises, resulting in a widened pulse pressure. Arterial pulses should be measured, either directly or indirectly, using a tail cuff. Pulse pressures in excess of 60 mm Hg and diastolic pressures less than 50 mm Hg are consistent with more severe AR, and progression of the regurgitation is likely.

Echocardiographic Findings

The most common echocardiographic finding on the aortic valve in horses with AR is a linear echo in the left coronary cusp, parallel to the free edge of the leaflet, which is a degenerative change (Fig. 14). Nodular thickening of the free edge of the aortic leaflet is a less common degenerative change or can occur secondary to a healed bacterial endocarditis lesion. Both parallel fibrous band lesions and nodular changes are the most common changes seen at postmortem examination on the aortic valve leaflets in horses with diastolic murmurs. AVP is also common in horses, most frequently involving the noncoronary cusp of the aortic valve and is typically mild. Care must be taken in diagnosing AVP; the prolapse should be visible in both short and long axis views, and in the long axis view, the ascending aorta should clearly be visualized with the aortic valve centered in the image. Much less frequently, fenestration of the leaflet is present or the aortic leaflets are redundant, flail, malformed (congenital or acquired), or severely prolapsing or have vegetative lesions. Although fenestration of the leaflets have been reported in horses with severe AR, they are often thought to be an incidental finding at postmortem examination. Flail aortic leaflets are rare and can be associated with acute onset of severe AR. Congenital AR is rare and is usually associated with a dysplastic aortic valve. AR can also occur in horses with a VSD, an aortocardiac fistula (ACF), or other aortic root abnormalities. Bacterial endocarditis, although rare, occurs with equal frequency on the aortic and mitral valves.

Diastolic high frequency vibrations of the free edge of the aortic valve leaflet, usually the left coronary cusp, are detected in horses with musical murmurs throughout diastole (Fig. 16; Vibrating Aortic Valve Movie). High frequency vibrations of the septal leaflet of the mitral valve or the interventricular septum occur secondary to the turbulent AR jet, impinging on either the septal leaflet of the mitral valve or the interventricular septum, respectively. These high frequency vibrations are best imaged with M-mode echocardiography due to its high sampling rate (Fig. 17). As the AR worsens, left ventricular enlargement ensues, along with increased systolic thickening of the interventricular septum and left ventricular free wall secondary to the increased stretch. Fractional shortening also increases initially in response to the increasing left ventricular volume overload. However, in some AR horses, fractional shortening may not increase with the dilatation of the left ventricle, as both the diastolic and systolic dimensions of the left ventricle increase. The absence of an increase in fractional shortening with a significant increase...
in the left ventricle. The left ventricular internal diameter is an indication of early left ventricular dysfunction. Rounding of the left ventricular apex occurs as the left ventricular volume overload develops. The left ventricle also increases in length in horses with AR. Once there is significant chronic AR, the stroke volume increases and dilatation of the aortic root will be evident. Early systolic closure of the mitral valve and an increased septal to E-point separation may also be detected. No change in the left ventricular free wall thickness occurs with mild, moderate, or severe AR, consistent with eccentric hypertrophy. However, when the AR is more severe, thinning of the interventricular septum and left ventricular free wall occurs along with a decrease in the relative wall thickness. A swinging pattern of interventricular septal motion develops as the AR worsens, secondary to the increasing left ventricular volume and pressure overload that occurs throughout diastole. Right ventricular diastolic compression occurs as the severity of the AR increases (Fig. 18). As the AR worsens, left atrial enlargement develops due to volume retention in the left atrium, left ventricular dysfunction, or left ventricular or mitral annulus dilatation, leading to MR. Also, the duration of the pre-ejection period (PEP) decreases due to increased left ventricular end diastolic pressure and decreased end diastolic aortic pressure.

Although the use of fractional shortening to evaluate myocardial function in horses with AR has its limitations, a normal fractional shortening in the face of a significantly enlarged left ventricular internal diameter at end diastole is an indication of left ventricular dysfunction. An even more significant indication of decreased left ventricular function is a decreased fractional shortening. This change is something that is usually only detected late in the disease in horses with chronic AR. Horses with severe AR have a trend toward a decreased fractional shortening, decreased fractional area change, and decreased ejection fraction. TDI is a more sensitive technique for the evaluation of myocardial function and may be able to better identify left ventricular dysfunction in horses with AR. More work needs to be done in this area to determine if this will have prognostic value.
Color-flow Doppler echocardiography reveals the jet of AR, originating around the leaflets, most frequently from the center where the three semilunar cusps coapt, often extending around the left coronary cusp. The jet of AR usually extends apically and toward the left ventricular free wall, along the septal leaflet of the mitral valve (Fig. 19), creating the high frequency vibrations of this leaflet seen on M-mode and 2D echocardiography. However, the regurgitant jet may also extend toward the interventricular septum, causing the high frequency vibrations seen there (Aortic Regurgitation Jet Movie). Rarely, high frequency vibrations are imaged on the left ventricular free wall associated with severe AR (see Fig. 17B). Continuous-wave Doppler echocardiography can be used to obtain a pressure half-time of the AR jet (Fig. 20), taking care to align the ultrasound beam as close to parallel with the regurgitant jet as possible.

Several echocardiographic findings have been associated with increasing severity of AR, but more studies are needed to further identify echocardiographic findings associated with increasing AR severity. Increased end diastolic pressures result in the premature closure of the mitral valve, an indication of increased AR severity. The difference in the aortic root diameter at the sinotubular junction in early diastole immediately after aortic valve closure compared with its diameter in late diastole right before aortic valve opening is associated with the severity of AR. An increasing severity of AR is also associated with a shorter PEP. The shorter PEP is due to the higher end diastolic left ventricular pressure and the lower aortic pressure at the end of diastole that develops as AR worsens. The size of the regurgitant jet relative to the size of the left ventricular outflow tract and the length of the regurgitant jet have been proposed as methods of assessing severity but have many limitations.

Evaluation of the narrowest portion of the jet at or just below its origin (vena contracta) and looking for acceleration of the jet proximal to its origin in humans to assess the severity of the regurgitation and may be useful in horses, taking into account their inherent limitations. Late diastolic MR is an indication of elevated left ventricular end diastolic pressure in humans with severe AR and has been detected in horses with severe AR (Fig. 21). A short pressure half-time and a low velocity time integral are indications of increasing left ventricular pressure half-time.
pressure and more severe AR. The increasing intensity of the spectral Doppler continuous-wave tracing of the AR jet is another indication of its severity.

Significance/Prognosis
In most instances, the AR progresses slowly and, therefore, often does not result in a shortened life expectancy. If, however, AR occurs at a young age or is moderate to severe when first detected, the regurgitation could become severe enough to affect performance or life expectancy.

The development of MR indicates progression of the AR, and the combination of AR and MR is often enough to affect performance and may ultimately affect life expectancy (Fig. 22). The use of the ACE inhibitor benazepril is recommended in horses with moderate or severe AR to reduce afterload, with similar improvements in fractional shortening and cardiac output as in horses with MR. A decrease in aortic sinus diameter and percentage of the aortic annulus diameter occupied by the AR jet can be expected in treated horses.

The detection of ventricular arrhythmias in horses with moderate or severe AR is a cause for...
concern. Compared with other valvular regurgitation, horses with AR have an increased relative risk of experiencing ventricular arrhythmias.\(^{33}\) The presence of ventricular arrhythmias increases the likelihood for progression of the AR within 2 years.\(^{33}\) An exercising ECG should be performed in all horses with moderate or severe AR to look for exercise-induced ventricular premature complexes (VPCs).\(^{33,39}\) A continuous 24-hour ECG is also recommended in these horses.\(^{33}\)

Death can also occur suddenly in horses with moderate to severe AR, secondary to fatal ventricular arrhythmias.\(^{39,63}\) The risk for exercise-induced ventricular arrhythmias is higher in horses with severe AR. This is due to the reduced myocardial perfusion from the low diastolic pressures and the increased myocardial excitability secondary to myocardial ischemia associated with increased myocardial oxygen demand and reduced oxygen delivery.\(^{63}\) Horses with moderate to severe AR and left atrial enlargement are also at increased risk for the development of AF.\(^{33}\) This may be due in part to the increased likelihood for APCs to be detected in horses with severe AR. APCs and left atrial enlargement are both risk factors for the development of AF. The detection of AF in a horse with pre-existing AR is an indication of significant left-sided cardiac enlargement and worsening AR. The onset of AF often is the beginning of the deterioration of the horse’s cardiovascular status. Although the development of CHF secondary to severe AR is uncommon, it does occur in horses who develop significant AR at an early age, or with acute severe AR.

Determining the significance of the AR involves consideration of the character of the arterial pulses, the pulse pressure (difference between peak systolic and end diastolic pressure), lesions detected on the valve, changes in the cardiac chamber and great vessel size, myocardial function, Doppler indices of AR severity, and the arrhythmias detected at rest and during exercise, if any (Table 1).\(^{33,39}\) The horse’s age, use, owner’s expectations, other murmurs, and clinical signs of cardiovascular disease must also be considered. According to the recent American College of Veterinary Internal Medicine/European College of Equine Internal Medicine consensus statement, horses with severe AR should not be ridden by a child, used as a lesion horse, or compete in high-risk sports due to the risk of sudden cardiac death (SCD).\(^{39}\) Regular follow-up echocardiographic and exercising ECGs are important to monitor the progression of the AR with the intervals between examinations based on the severity of the AR and the presence of ventricular arrhythmias or AF.\(^{39}\)

**Ventricular Septal Defect**

A VSD is the most common congenital cardiac abnormality in horses.\(^{85,89}\) VSDs are more prevalent in Section A Welsh Mountain ponies\(^{80}\) and also appear to be more common in Standardbreds\(^{85}\) and Arabians.\(^{85,91}\) The most common location for the VSD is in the membranous or perimembranous portion of the interventricular septum. The typical murmur associated with the membranous or perimembranous VSD is a grade 4–6/6 coarse band-shaped pansystolic murmur, with its PMI in the tricuspid valve area. A murmur is also heard in the pulmonic valve area that is usually slightly softer, slightly shorter in duration (usually holosystolic) and more crescendo decrescendo in quality. An increased volume of blood ejected across a normal pulmonic valve causes this relative pulmonic stenosis murmur. If the murmur in the pulmonic valve area is louder, it is likely that the VSD is either located in the outflow portion of the interventricular...
septum, there is a VSD with pulmonic stenosis, or Tetralogy of Fallot is present.

**Echocardiographic Findings**

The typical membranous or perimembranous VSD is not visible in the four-chamber view. This VSD is imaged in the left ventricular outflow tract view just ventral to the right coronary or noncoronary cusp of the aortic valve and beneath the septal leaflet of the tricuspid valve (Fig. 23; VSD Movie). The aortic leaflet often occupies a portion of the defect, making it appear smaller than it actually is. In some horses, a large portion of the aortic valve prolapses into the defect, restricting flow through the defect. A VSD in the outflow portion of the interventricular septum is much more difficult to detect. An outflow defect is usually best visualized in the short axis view imaging right below the aortic valve in its typical subaortic/subpulmonic location (Fig. 24). Imaging an outflow defect in the long axis view is difficult because it is located between the left and right outflow tract views. Defects elsewhere in the muscular septum are uncommon; however, thorough examination of the interventricular septum should be performed to look for these VSDs. Measuring the size of the defect in two mutually perpen-

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![Fig. 23. Long (A) and short (B) axis echocardiograms of a perimembranous VSD. A, The margins of the VSD are denoted by the arrows. This image was obtained in the right parasternal long axis view of the left ventricular outflow tract (LVOT). B, The margins of the VSD are denoted by the arrows. This image was obtained in the right parasternal short axis view of the aorta. RV, right ventricle; RA, right atrium; AO, aorta; LCC, left coronary cusp; PA, pulmonary artery; LAA, left atrial appendage; TV, tricuspid valve; NCC, noncoronary cusp; RVOT, right ventricular outflow tract; RCC, right coronary cusp; LA, left atrium. The V at the top right of the image indicates the orientation of the transducer which is dorsal in image A and cranial in image B.](image1)

![Fig. 24. 2D (A) and color-flow Doppler (B) echocardiograms of an outflow VSD (arrow) and the associated shunt (arrow) in the right parasternal short axis view just below the aortic valve. LVOT, left ventricular outflow tract; RVOT, right ventricular outflow tract; LA, left atrium; PV, pulmonic valve. The right side of both images is cranial.](image2)
dicular planes should be performed to obtain an idea of its size. In adult horses, a small VSD is \( \leq 2.5 \) cm, a moderate-sized defect is \( 2.5-3.5 \) cm, and a large defect is \( >3.5 \) cm. In foals, ponies, or horses of different sizes, the size of the VSD should be compared with the size of the aortic root if the aortic root is normal. A VSD larger than 1/3 the diameter of the aortic root is consistent with a large defect.

Increased systolic thickening of the interventricular septum and left ventricular free wall are present, along with an increased fractional shortening associated with the left ventricular volume overload, if the left ventricular function is normal. Mild pulmonary artery enlargement is also often present if there is a moderate to large VSD, associated with the increased flow secondary to the left to right shunt.

Color-flow Doppler echocardiography reveals the acceleration of flow on the left ventricular side of the defect, with turbulent blood shunting through the defect into the right ventricle (Fig. 25; VSD Color Jet Movie). A peak shunt velocity \( >4.5 \) m/s obtained with continuous-wave Doppler echocardiography is compatible with a restrictive VSD (Fig. 26).

Significance/Prognosis

The most important determinants of the VSD’s significance are its size and its shunt velocity, which is an indication of its hemodynamic impact (Table 1). Other factors need to be considered, however, including the degree of left atrial and left ventricular volume overload, left ventricular function, the presence of AVP into the defect, and the severity of AR or MR, if present. Horses with small VSDs can have a normal life expectancy and are usually present in CHF, often by the time they are 5 or 6 years of age. Although horses with small VSDs can race successfully, they do not compete successfully in the top tier of racing. Few Thoroughbreds with a VSD race successfully, and those that do are usually racing short distances (5 or 6 furlongs).

Standardbreds can race successfully with small VSDs if their VSD is 2.8 cm or smaller, although not in the top tier. In other disciplines, horses can compete successfully with small VSDs. In one report, horses with a VSD detected as an incidental

![Fig. 25. Color-flow Doppler echocardiograms of the high-velocity shunt through a perimembranous VSD in long (A) and short (B) axis. The arrows denote the margins of the VSD. A, This image was obtained in the right parasternal long axis view of the left ventricular outflow tract (LVOT). B, This image was obtained in the right parasternal short axis view of the aorta. RA, right atrium; RV, right ventricle; AO, aorta; LAA, left atrial appendage; PA, pulmonary artery; NCC, noncoronary cusp; RCC, right coronary cusp; LCC, left coronary cusp; RVOT, right ventricular outflow tract. The V at the top right of the image indicates the orientation of the transducer which is dorsal in image A and cranial in image B.](image1)

![Fig. 26. Continuous-wave Doppler spectral tracing of the left to right flow through the VSD with the corresponding color-flow Doppler echocardiogram demonstrating the shunt. The peak systolic shunt velocity through the VSD (arrow) exceeds 5 m/s. The V at the top right of the image indicates the orientation of the transducer which is dorsal in this image.](image2)
finding had a VSD diameter of $1.83 \pm 0.83$ cm compared with a VSD diameter of $4.40 \pm 0.99$ cm in those presenting with exercise intolerance or CHF. In these same horses, the ratio of the VSD diameter to aortic root diameter in those with no clinical signs was $0.31 \pm 0.18$ compared with a ratio of $0.64 \pm 0.06$ in those clinically affected. Horses with a peak shunt velocity through the VSD $>4$ m/sec have performed successfully in racing, whereas those with slightly lower peak velocities may be able to perform successfully in less demanding athletic events. MR is common in middle age to older horses with small to medium sized VSDs, secondary to the left atrial and left ventricular volume overload and mitral annular stretch. AR may develop over time, especially in horses with AVP into the VSD. The noncoronary cusp of the aortic valve tore in one horse with VSD and aortic prolapse, resulting in a flail aortic valve, massive AR, and CHF. CHF develops with large VSDs, associated with increasing right ventricular pressure, and a resultant decreased shunt velocity. The development of AF in a horse with a VSD is secondary to left atrial enlargement and often signifies impending cardiac decompensation or occurs concurrently with the onset of CHF.

**Aortocardiac Fistula**

ACF is an uncommon problem that is diagnosed more frequently with the awareness of its clinical presentation and the advent of 2D and color-flow Doppler echocardiography. First described echocardiographically in 1986, when only M-mode echocardiography was available, ACF has been a recognized risk factor for SCD in horses, particularly stallions, since the 1960s. ACFs are most common in middle-aged male horses and are associated with a rupture of the aortic root at the sinus of Valsalva or rupture of a pre-existing sinus of Valsalva aneurysm. However, ruptured sinus of Valsalva aneurysms and aortic root ruptures have occurred in young horses. Unruptured sinus of Valsalva aneurysms have been reported in two 3-year-old Thoroughbred geldings and in an 18-year-old Quarter Horse cross gelding (the latter subsequently developed an ACF). Sinus of Valsalva aneurysms can be congenital or acquired.

Affected horses often present with acute colic, normal gastrointestinal sounds, and disproportionate tachycardia, although some have presented with exercise intolerance or their abnormalities were detected on a routine examination. A thorough examination reveals a normal gastrointestinal tract and bounding arterial pulses; frequently, there are jugular pulses and a rapid regular rhythm of $\geq 100$ bpm, usually ventricular tachycardia (VT). Most commonly, a continuous machinery murmur is present, with its PMI in the tricuspid valve area. However, combinations of both right and left sided systolic and diastolic murmurs have been reported in affected horses. Loud S3 may be detected associated with a left ventricular volume overload. Electrocardiography usually reveals uniform VT, VPCs, or, on occasion, normal sinus rhythm. Horses with an unruptured sinus of Valsalva aneurysm usually have a normal sinus rhythm. They may have no audible murmur, murmurs of right-sided systolic murmurs or murmurs of AR may be detected, possibly secondary to right ventricular outflow tract obstruction, or the loss of support of the aortic root. Although uncommon, ACFs have developed in horses with longstanding AR.

**Echocardiographic Findings**

Echocardiographic examination reveals disruption in the aortic root that is most commonly detected in the right sinus of Valsalva (Fig. 27; Aortocardiac Fistula Movie). A disruption of the aortic root at the sinus of Valsalva can be easily mistaken for a membranous VSD that is located immediately below the right and/or noncoronary cusp (see Fig. 23) while the aortic root rupture is within the sinus of Valsalva (see Fig. 27). A ruptured sinus of Valsalva aneurysm can occur in conjunction with a VSD, and although common in humans, has only been reported once in the horse. The ruptured sinus of Valsalva aneurysm appears as thin echoic fluttering membranous tissue protruding into the right ventricle or, less frequently, into the right atrium and may have the appearance of a windsock. The aortic root or sinus of Valsalva aneurysm usually ruptures into the right ventricle (Figs. 27 and 28). However, ruptures of the aortic root or sinus of Valsalva aneurysm into the right atrium, through the tricuspid valve, into the interventricular septum, or, least frequently, into the left ventricle have occurred. Dissection of blood subendocardially into the interventricular septum can frequently be detected, most frequently on the right side (Fig. 29). Although subendocardial dissection along the left side of the interventricular septum does occur (Fig. 30). This subendocardial disruption can also disrupt a chordae tendineae that inserts in that region. Color-flow Doppler echocardiography reveals high velocity turbulent flow shunting continuously from the aorta through the rupture into the right ventricle (Fig. 31), right atrium, or left ventricle, depending on the site of the rupture. High-velocity turbulent blood flow can also be seen in the subendocardial dissection, if present (see Fig. 29). Continuous-wave Doppler echocardiography will identify high-velocity turbulent blood flow in the shunt within the receiving chamber throughout systole and diastole (see Fig. 31). AR is also sometimes present in horses with ACFs. Horses with ACFs have an enlarged, volume overloaded right ventricle, pulmonary artery, left atrium, and left ventricle, if the fistula is from the aorta into the right ventricle. Right atrial enlargement would also be expected if the fistula connects to the right atrium. In the rare case with an aortic to
left ventricular fistula, only a left ventricular volume overload might be present. Left ventricular dysfunction, as evidenced by decreased fractional shortening, is also reported.

**Significance/Prognosis**

The detection of an unruptured sinus of Valsalva aneurysm or an ACF renders the horse unsafe to ride or drive; thus, the horse should be retired from performance. Horse handlers must be aware of the horse’s risk of experiencing collapse or SCD. Postulated mechanisms of SCD are disruption of the conduction system associated with the acute dissection of blood in the interventricular septum or secondary to a fatal ventricular arrhythmia. Horses with an ACF presenting with VT should be treated with antiarrhythmic drugs if the rate is over 120 bpm, R on T is present, the rhythm is multiform (rare), or the horse has clinical signs of cardiovascular compromise. Spontaneous resolution of the uniform VT or ventricular ectopy can occur in horses with ACFs but many need antiarrhythmic therapy for resolution of the VT. Elevation of cTnI or

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**Fig. 27.** Long (A) and short (B) axis echocardiograms of an ACF. A, Modified long axis view of left ventricular outflow tract showing the defect in the aortic root at the right sinus of Valsalva (arrows) which measured 1.2 cm in this plane. B, Short axis view of the aorta showing the defect in the aortic root at the right sinus of Valsalva (arrows), which measured 1.5 cm in this plane. RA, right atrium; RV, right ventricle; LVOT, left ventricular outflow tract; AO, aorta; PA, pulmonary artery; TV, tricuspid valve; RCC, right coronary cusp of the aortic valve; SMV, septal leaflet of the mitral valve; PV, pulmonic valve. The V at the top right of the image indicates the orientation of the transducer which is dorsal in image A and cranial in image B.

**Fig. 28.** Postmortem view of an ACF (arrows) from the right side of the heart. Notice the subendocardial dissection (up arrow) and the rupture underneath the septal leaflet of the tricuspid valve (horizontal arrow). RA, right atrium; TV, tricuspid valve; RV, right ventricle.

**Fig. 29.** Right parasternal long axis echocardiogram (LVOT view) of a subendocardial dissection (arrows) of blood down the right side of the interventricular septum in a horse with an ACF. RA, right atrium; RV, right ventricle; LVOT, left ventricular outflow tract; AO, aorta; LLA, left atrial appendage, PA, pulmonic artery. The V at the top right of the image indicates the orientation of the transducer which is dorsal in this image.
cTnI or cTnT should decrease rapidly with resolution of the VT, unless there is significant myocardial damage from the subendocardial dissection. Percutaneous closure of an ACF has been successfully performed using an Amplatz occluder device, although the horse developed CHF associated with worsening AR and MR.100

Life expectancy for horses with an ACF can vary from hours or days to months or years, with the majority of horses living a year or less following diagnosis.95,96 However, horses with a small restrictive ACF may live for 5 years or more. The size of the intracardiac shunt and the other associated cardiac abnormalities will help determine an individual horse’s life expectancy. Although these horses may experience SCD at any time, most develop signs of CHF and are humanely euthanized. Horses with an ACF, like all individuals with intracardiac shunts or high-velocity turbulent regurgitant blood flow, are at slightly increased risk of developing endocarditis, which was reported in one horse with an ACF.99

Aortic Rupture and Aortopulmonary Fistulation in Friesians
Aortopulmonary fistulas are acquired fistulas that occur in young Friesians, with the majority of horses being less than 7 years old.101 The aortic rupture is transverse, occurs just proximal to the ligamentum arteriosum, and usually results in an acquired fistula101–103 continuously shunting between the aorta and pulmonary artery. Pseudoaneurysms, periaortic hematomas, aortic dissection, and hemothorax have occurred with varying frequency at postmortem examination in acute, subacute, and chronic cases.101,103 Pseudoaneurysms have occurred in all reported chronic cases of aortic rupture in Friesians, in 50% of the subacute cases, and rarely in one (25%) of the acute cases.101 Periaortic hematomas occur primarily in the acute (50%) and subacute (62.5%) cases and were only detected in one chronic case.101 Hemothorax was detected in half of the acute cases and subacute cases. Aortic dissections are occasionally seen in subacute cases (3/8) and even less frequently in chronic cases (1/8).101 An underlying connective tis-

Fig. 30. Subendocardial dissection along the left side of the interventricular septum (arrow) in a horse with an ACF. This is the right parasternal long axis four-chamber view. RA, right atrium; RV, right ventricle; LA, left atrium; LV, left ventricle. The V at the top right of the image indicates the orientation of the transducer which is dorsal in this image.

Fig. 31. Color-flow Doppler echocardiogram of the shunt flow associated with an ACF. A, Modified right parasternal long axis echocardiogram of the left ventricular outflow tract showing the high velocity turbulent flow (arrow) shunting from the aorta into the right ventricle. B, Continuous-wave Doppler spectral tracing of the high velocity turbulent flow (arrow) shunting from the aorta into the right ventricle during diastole (D) and systole (S). RA, right atrium; RV, right ventricle; LVOT, left ventricular outflow tract; AO, aorta; LLA, left atrial appendage, PA, pulmonary artery. The V at the top right of the image indicates the orientation of the transducer which is dorsal in image A and cranial in image B.
sue disorder affecting either elastin or collagen in the aortic media is suspected in affected horses.103

Although SCD can occur, most horses have a subacute or chronic history of recurrent colic, anorexia, depression, repeated recumbency, poor performance, coughing, and epistaxis.101 Prior to diagnosis, peripheral edema (intermittent), fever, tachycardia, and tachypnea may be present. Bounding arterial pulses would be expected, with the continuous shunting from the aorta to the pulmonary artery, and occurred in approximately 50% of affected horses.101 Cardiac murmurs (all on the left) and jugular pulses were reported in half of the horses in this retrospective study and a few had cardiac arrhythmias.

Echocardiographic Findings

Reported echocardiographic findings in affected Friesians include a dilated pulmonary artery and dilated right atrium and right ventricle; the latter two are probably associated with the CHF that ensued.101 Pleural effusion, pericardial effusion, and pulmonary edema may also occur. With the use of nontraditional echocardiographic views and scanning out the aorta and pulmonary artery, the pseudoaneurysms104,105 can be imaged with 2D echocardiography, along with the turbulent flow in these structures using color-flow Doppler echocardiography. Transesophageal echocardiography has also visualized the aortic arch region better in affected horses.103,106

Significance/Prognosis

Friesian horses with aortic rupture or aortopulmonary fistulation have a grave prognosis for life, with most living only days to weeks following the onset of clinical signs.103 Right-sided CHF is common with pulmonary hypertension and right atrial and ventricular enlargement detected echocardiographically. Although treatment for CHF can be instituted, affected horses are not safe for ridden or driven work. Humane destruction is suggested due to the severity of the disease and the likely underlying genetic disorder.

5. Myocardial Disease with Emphasis on Diagnosis, Severity, and Impact on Performance, Life Expectancy, and Horse and Rider Safety

Myocarditis, myocardial necrosis, fibrosis, and fatty and fibrofatty infiltrates can cause SCD by triggering fatal ventricular arrhythmias. At postmortem examination, there may be no other cause of death found or myocardial lesions are found that could have resulted in a fatal ventricular arrhythmia. This is reported most frequently in young racehorses that experience SCD.107 Infrequently, VT is documented shortly before death.107 Multifocal myocardial necrosis or fibrosis has been documented histopathologically in some of these horses. These lesions were found close to the sinoatrial node, in the AV junction, and in the upper portion of the interventricular septum in one study, along with vascular changes.107 Fibrous, fatty or fibrofatty infiltrates in the myocardium have been found in horses of all ages with fatal ventricular arrhythmias/SCD and may be similar to changes seen with arrhythmogenic cardiomyopathy in humans.108–110

With the advent of echocardiography, myocardial disease is identified more frequently in horses with a variety of clinical presentations. Many young horses with suspected myocarditis have a history of fever in the days, weeks, or months preceding the onset of clinical signs. Myocardial disease may be associated with exercise intolerance, poor performance, collapse, tachycardia that is disproportionate to fever, arrhythmias, and/or murmurs or be clinically silent.111,112 The first indication of myocardial disease may be SCD in one or more horses.111 Myocardial disease can be associated with infection (viral, bacterial, or fungal), colic, sepsis, toxemia, drugs (ionophores), plants, envenomation, hypoxemia, amyloidosis, nutritional, glycogen storage disease, neoplastic infiltration, endocarditis, trauma, severe hemorrhage, catecholamines, cocaine, and cobalt, as well as other causes. Myocardial contusion should be considered as a possibility in horses with cranial thoracic trauma.113

Cardiac auscultation may be normal or arrhythmias or murmurs of MR or TR may be present. The valvular regurgitation usually develops secondary to stretching of the AV valve annulus in a horse with primary myocardial disease. Frequent atrial or ventricular extrasystoles, sustained atrial tachycardia or VT, or multifocal arrhythmias are often indicative of primary myocardial disease.111,112 Resting, exercising, or continuous 24-hour electrocardiography may be needed to identify arrhythmias in affected horses. Some arrhythmias associated with myocardial disease, such as multifocal VT, are life threatening. Resting heart rates in horses with myocardial disease may be normal or elevated, but affected animals usually have elevated exercising heart rates and prolonged heart rate recovery after exercise. cTnI or cTnT may be elevated in horses with active myocardial disease.114 Tachycardia and arrhythmias (both atrial and ventricular) are common problems in horses presenting with cardiac involvement associated with acute envenomation.115,116 An elevated cTnI is also detected in a number of bitten horses, consistent with myocardial injury.116 In many horses with acute envenomation, tachycardia persists through the time of discharge from the hospital.

Ionophore Toxicity

SCD of one or more horses may be the first indication of ionophore toxicity.117–129 A myriad of other clinical signs, such as anorexia, lethargy, muscle weakness, colic, diarrhea, neurological signs, polyuria, and polydipsia, may also occur in horses with ionophore exposure.20,118–135 Arrhythmias are also reported in horses with monensin poisoning,117,118,121–123 as well
Elevations of creatinine kinase and lactate dehydrogenase and their cardiac isoenzymes have been reported in monensin-exposed horses \(^{118,123}\) and in salinomycin- and lasalocid-exposed horses \(^{125,135}\) but are less sensitive and specific than measuring the cardiac troponins when looking for evidence of myocardial cell damage. \(^{120}\) Significant increases in cTnI have been reported in horses with monensin toxicosis, with the initial increase occurring between 24 and 72 hours after administration. \(^{127}\) The two horses with the most marked elevations of cTnI died or were euthanized within 5 days of monensin administration, and their postmortem examinations confirmed severe cardiac disease with myocardial necrosis, degeneration, fibrosis, and infiltration of lymphocytes, macrophages, and rare neutrophils. \(^{127}\) Significant increases in cTnI have also been reported in horses with lasalosid exposure. \(^{20,126}\)

Postmortem examination in the peracute cases of ionophore toxicosis may reveal no lesions in the myocardium. Monensin can be detected in serum, blood, urine, liver, myocardium, and gastric contents. However, higher concentrations of monensin have been reported in myocardial tissue in most horses than in these other fluids, tissues, or in gastric contents. Therefore, myocardial tissue analysis for monensin in outbreaks of suspected poisoning is preferable. \(^{117}\) Whenever possible, feed samples should also be submitted for analysis. In subacute cases, myocardial necrosis and fibrosis is usually detected, with thinning of the myocardium or fibrosis predominating in chronic cases. \(^{123}\)

Arrhythmias are commonly detected in horses with ionophore poisoning, with VT being most life threatening. \(^{126}\) Significant increases in cTnI have been reported in horses with lasalocid poisoning that persisted for at least 2 months in some affected horses. \(^{126}\) The highest cTnI detected was in the one horse with the most severe VT and markedly depressed left ventricular function. \(^{126}\)

**Echocardiographic Findings**

Echocardiography is the technique of choice for evaluating the myocardium and its function. The echocardiogram from horses with non-life-threatening arrhythmias associated with suspected myocarditis is usually normal, except for the abnormal opening and premature closure of the AV and semilunar valves that occur with both atrial and ventricular premature depolarizations. Ejection time may be shortened or absent altogether, particularly with very early VPCs. VPCs may cause abnormalities of interventricular septal motion. Severe myocardial necrosis occurs infrequently in horses with myocarditis and is usually associated with multifocal ventricular arrhythmias. When severe, the horses may present with acute CHF. Marked myocardial dysfunction is often detected echocardiographically with severe myocardial necrosis.

The most common echocardiographic finding detected in a horse with myocardial disease is impaired systolic function of the left ventricle. Low normal to low fractional shortening and focal or global hypokinesis or dyskinesis may be detected. A decreased fractional shortening below 28–30% in a horse with a normal resting heart rate and rhythm is an indication of left ventricular systolic dysfunction. Fractional shortening <24% in horses with AF is suggestive of concurrent myocardial dysfunction (Fig. 32; \(^{136}\) **LV Dysfunction Movie**). When the heart rate increases, fractional shortening should also increase; a factor that needs to be considered in a horse with sinus tachycardia during the echocardiographic examination. An increased end diastolic left ventricular internal diameter should cause an increase in fractional shortening via Starling’s law (increased stretch results in increased contractility). With left ventricular enlargement, fractional shortening should progressively increase as the left ventricular volume increases and can range from 40–60% in a horse with a normal resting heart rate and rhythm. Therefore, a fractional shortening of 30–40% in a horse with an enlarged left ventricular chamber is an indication of left ventricular systolic dysfunction and underlying myocardial disease. A thinner than expected left ventricular free wall (1.8 cm) and a large right ventricle (RV). Notice also the irregularly irregular rhythm of AF. The V at the top right of the image indicates the orientation of the transducer which is cranial in this image.
Dilation of the left ventricle in the absence of valvular regurgitation is another echocardiographic indication of underlying myocardial disease, as is disproportionate enlargement of the left ventricular chamber with mild MR and/or AR and no detectable valvular pathology. Dilated cardiomyopathy occurs in the horse and may be a sequel to myocarditis. A dilated left ventricular chamber with thinning of the interventricular septum and left ventricular free wall and decreased fractional shortening are typical hallmarks of dilated cardiomyopathy. Segmental wall motion abnormalities may also be present. Spontaneous contrast (“smoke”) may be imaged in the left atrium, left ventricle, and aorta, associated with the low-flow state. Severe myocardial necrosis leading to cardiac chamber enlargement, valvular regurgitation, and, in some cases, CHF, is a recognized significant sequelae to evenomation.115

Similarly, although less frequent, right ventricular enlargement and thinning of the right ventricular free wall may be detected in horses with right ventricular cardiomyopathy. Abnormalities of right ventricular free wall and interventricular septal motion are usually present. Marked TR and right atrial enlargement occur secondary to the severe right ventricular myocardial dysfunction. This is typically secondary to a fibrofatty infiltration of the myocardium.108,109,138 This condition is similar to arrhythmogenic right ventricular cardiomyopathy in Boxer dogs and humans, characterized clinically by collapse, arrhythmias, heart failure, and SCD. A fibrofatty infiltration of the right ventricle (left ventricular involvement may also be present) is found in these patients at postmortem evaluation.108,109,138 Although biopsies of the right atrial and ventricular myocardium have been successfully obtained in normal horses, this technique has not yet been applied to patients with suspected myocardial disease and is not without risk.139

As the left ventricular function deteriorates, aortic root diameter becomes smaller than normal with a shortened ejection time and little or no movement of the aortic root, associated with low cardiac output. Little systolic separation of the aortic or pulmonic valve leaflets is present. The pulmonary artery is usually dilated, secondary to pulmonary hypertension. The distance between the interventricular septum and peak opening of the mitral valve in early diastole (E-point to septal separation) and slope of the mitral valve as the rapid ventricular filling phase ends (EF slope) may be decreased. Delayed systolic closure of the AV valves may also occur in horses with left ventricular failure. Valve leaflets are usually normal but may appear thickened in horses with valvular regurgitation secondary to marked cardiac enlargement and dilation of the AV valve annulus. Right-sided cardiac enlargement usually develops secondary to the left-sided failure leading to pulmonic and TR.

Left ventricular wall motion, as assessed with TDI and speckle tracking, has demonstrated myocardial disease in horses with atypical myopathy in Europe. Seasonal pasture myopathy identified in the Midwestern United States and Eastern Canada is similar to the European atypical myopathy140 and is associated with ingestion of hypoglycin A within the seed of the box elder tree.141 In three affected horses, echocardiographic findings were reportedly normal (study was retrospective), although myocardial degeneration and necrosis was detected at postmortem examination in 50% of affected horses.140 While cardiac chambers sizes were normal in all horses with atypical myopathy, systolic wall motion abnormalities were detected in all affected horses.25 Biphasic contraction, most evident in the interventricular septum, was detected in the majority of horses, with a more “plateau shaped” motion seen in the remaining horses. This abnormal wall motion was also detected with TDI and 2DST strain analysis, confirming delayed ventricular repolarization and abnormal myocardial relaxation.25 The abnormal myocardial wall motion disappeared in the surviving horses. Both TDI and 2DST may be more sensitive for detecting early myocardial injury in affected horses.25 Investigation of the applicability of TDI and 2DST for horses with myocardial disease/cardiomyopathy is ongoing.

Areas of increased myocardial echogenicity are infrequently detected in horses and usually represent areas of myocardial fibrosis and fatty or fibrofatty infiltrate (Fig. 33; LV Scar Movie).

Horses with these findings often have a history of ventricular arrhythmias, although it is unknown if these areas of abnormal myocardial echogenicity are the cause of the arrhythmia. A large echoic area in left apical free wall was imaged at presentation in a horse with VT that was successfully converted. Two years later at postmortem examination, a thin,
extensive fibrotic area was present in this area, consistent with an infarct. Hypertrophy has also been detected in horses with fibrofatty infiltration of the myocardium and is especially prominent in horses with fibroadipose cardiomyopathy. These gross and histopathological changes are similar to arrhythmogenic right ventricular cardiomyopathy in humans. An inflammatory cell infiltrate, amyloid deposition, calcification, myocardial necrosis, or neoplasia may also cause increased myocardial echogenicity. Marked myocardial thickening and hyperechogenicity with hypokinesia were present in one horse with infiltrative cardiomyopathy and systemic amyloidosis.

Lymphosarcoma and hemangiosarcoma most commonly infiltrate the equine myocardium but do so infrequently. Primary hypertrophic cardiomyopathy has been reported in one horse and reversible hypertrophic cardiomyopathy in one horse with clostridial myonecrosis. Hypertrophic cardiomyopathy has been reported in horses with systemic hypertension, most commonly secondary to chronic renal disease. Hypertrophy has also been detected in horses with metabolic syndrome, secondary to the elevated insulin concentrations.

**Ionophore Toxicity**

Monensin toxicity causes marked depression in myocardial function. In acute monensin toxicosis, the cardiac chambers may be normal sized, but there is a marked decrease in myocardial contractility. Fractional shortening can be extremely low, <10%. Areas of myocardial dyskinesia in the interventricular septum are imaged and/or paradoxical septal motion is detected. Marked amounts of spontaneous contrast may be imaged in the left atrium, left ventricle, aorta, and on the right side of the heart. A flat aortic root with no systolic aortic root movement and premature closure of the aortic valve may also be detected. Scattered foci of increased myocardial echogenicity are frequently detected with acute monensin toxicosis. An anechoic pericardial effusion may be detected in severely affected horses. In horses that survive an acute exposure to monensin, left ventricular dilation, thinning of the left ventricular free wall and interventricular septum, decreased relative wall thickness, and decreased fractional shortening (20–30%) are frequently detected. AV valvular insufficiency may develop in horses with marked ventricular dilation and may result in a delayed presentation. However, some horses with mild decreases in left ventricular function detected in the acute phase recover normal myocardial function. In herd exposures to ionophores, there are also horses with normal myocardial function, most likely associated with decreased consumption of contaminated feed.

**Significance/Prognosis**

Persistent myocardial dysfunction impairs athletic performance in horses; the degree of this impairment depends upon its severity and the job that the horse is expected to perform. The findings on the echocardiogram in horses with myocarditis or cardiomyopathy can be very useful in formulating a prognosis. The horses with cardiac arrhythmias and normal myocardial function have an excellent prognosis for return to performance and normal life expectancy, once the arrhythmia resolves. The horses with severe left ventricular dysfunction and low cardiac output have a guarded to grave prognosis for life, as irreversible myocardial injury is usually present.

**Ionophore Toxicity**

A year or more following exposure, surviving horses may be clinically normal or may be poor doers, exhibiting poor performance, exercise intolerance, or even signs of CHF, consistent with ionophore-induced cardiomyopathy. Of the ionophores studied in horses, the myocardial injury with salinomycin has been reported to be less severe. The echocardiogram is an excellent predictor of outcome in horses with exposure to monensin, and this is likely to be the case with exposure to other ionophores. Fractional shortening was the best predictor of outcome in horses with monensin toxicosis during several outbreaks. Horses with fractional shortening <20% had a guarded to grave prognosis for life. These horses may die from low output heart failure or have severe cardiac damage and are unlikely to be useful individuals, if they survive. Horses with fractional shortening of 20–30% are likely to survive. Some may be “cardiac cripples” and are only able to perform low-level physical activity. Other horses with mild decreases in left ventricular function detected acutely after exposure return to normal after a prolonged period of rest. These horses are able to successfully return to work. A normal echocardiogram in horses recently exposed to monensin is a good prognostic indicator, as these horses have been able to return successfully to performance after a period of rest and have not developed delayed cardiovascular signs in the ensuing years. A normal resting and postexercise echocardiogram in horses exposed to monensin one year earlier was associated with an
excellent prognosis for returning to previous performance.\textsuperscript{125,126}

ECG abnormalities or elevations of creatinine kinase or lactate dehydrogenase isoenzymes have not been good prognostic indicators of outcome in earlier outbreaks of monensin toxicity.\textsuperscript{118,123} Evaluation of cTnI or cTnT has since replaced the measurement of the cardiac isoenzymes.\textsuperscript{126,128} In horses with lasalocid poisoning, cardiac arrhythmias and elevations in cTnI were more common than echocardiographic abnormalities.\textsuperscript{126} cTnI concentrations also increased in several of the horses during the follow-up period, instead of decreasing as expected, suggesting ongoing myocardial injury. In the one horse with the hyperechoic myocardium, the cTnI concentrations remained high for 5 months but had returned to normal at the time of euthanasia after one year of rest. Myocardial fibrosis was confirmed at postmortem examination. Myocardial degeneration was detected in all horses that had a postmortem examination performed, and fibroblast proliferation or fibrosis was detected, along with infiltration of macrophages, neutrophils, and lymphocytes.\textsuperscript{126}

6. Pericardial Disease with Emphasis on Diagnosis, Severity, and Impact on Performance, Life Expectancy, and Horse and Rider Safety

Pericarditis is an occasional problem in horses but can have devastating consequences when not diagnosed and treated aggressively. Pericarditis may be idiopathic\textsuperscript{149–154} or immune mediated,\textsuperscript{149,150,155} viral,\textsuperscript{156} bacterial,\textsuperscript{150,151,154,156–163} traumatic,\textsuperscript{164–166} fungal,\textsuperscript{167,168} iatrogenic,\textsuperscript{169} or neoplastic (rare).\textsuperscript{170–173} In horses with concurrent pleuropneumonia, pericarditis is thought to be secondary to the pre-existing infection in the lungs and/or pleural cavity.\textsuperscript{156,174,175} A cluster of pericarditis cases occurred during the mare reproductive loss syndrome (MRLS) in Kentucky. These cases were associated with exposure to the Eastern tent caterpillar in the spring and summer.\textsuperscript{176–178} Hairs of the ingested eastern tent caterpillar may disrupt the mucosal barrier in the gastrointestinal tract. This may be how bacteria gain access to the circulation, creating the bacteremia and infections seen in horses with MRLS. The Actinobacillus sp. found in the pericardial fluid of affected horses was identical to the species found in the oral cavity and gastrointestinal tracts of healthy horses.\textsuperscript{176,179,180} Although pericarditis is primarily a disease of adult horses, it does occur occasionally in foals.\textsuperscript{160,161,181,182}

Pericardial masses are infrequently detected in horses and are usually associated with pericardial abscesses or neoplasia. Pericardial abscesses are rare in horses but have been imaged in one horse with myocardial involvement.\textsuperscript{150} More frequently, cranial mediastinal abscesses mimic the clinical signs of pericarditis by causing cranial vena caval obstruction or by compressing the right atrium and/or right ventricle. Mesotheliomas, probably the most common pericardial tumor in horses, have been detected echocardiographically. Pericardial effusion is usually detected in horses with mesothelioma.\textsuperscript{170–172} Hemangiosarcoma of pericardial origin has been reported.\textsuperscript{173} Lymphosarcoma also occasionally invades the pericardium, usually in horses with cranial mediastinal lymphosarcoma. Horses with thoracic melanoma may also have pericardial involvement.

Fever, depression, anorexia, poor performance or exercise intolerance, colic, weight loss, peripheral edema, generalized venous distention, tachycardia, and muffled heart sounds are common in affected horses.\textsuperscript{149–151,154,156,163,166} Pericardial friction rubs are often present in horses with smaller pericardial effusions.

Echocardiographic Findings

Echocardiography is extremely useful in diagnosing pericardial effusion, characterizing the effusion, determining where to perform a pericardiocentesis, and monitoring the response to therapy.\textsuperscript{149,150,153,156,163,183} With small effusions, there is fluid imaged between the pericardium and epicardium, only in systole. Sheets of fibrin, fibrin strands, and loculations are frequently detected, as fibrinous pericarditis is common.\textsuperscript{150,178,183} Swirling echogenic fluid in the pericardial sac is most consistent with hemorrhage, whereas a clear anechoic effusion suggests a transudate, which can be present in horses with CHF. A composite or more echogenic fluid with fibrin is typical of septic or traumatic pericarditis. Hyperechoic free gas echoes are rarely imaged in horses with pericarditis and, if detected, a penetrating wound or traumatic pericarditis should be suspected. The most reliable sign of early pericardial effusion is the collapse of the right atrium. Right ventricular diastolic collapse, an excellent indicator of cardiac tamponade and hemodynamically significant pericardial effusion, develops with more effusion (Fig. 34).\textsuperscript{149,150,152,165,183} The left ventricle is smaller than normal with significant pericardial effusions, and there is loss of the normal left ventricular free wall and pericardial motion. The motion of the interventricular septum may be increased or paradoxical with larger pericardial effusions. Excessive cardiac motion occurs and often corresponds to the electrical alternans detected electrocardiographically.

In horses with chronic pericarditis, the fibrin in the pericardial space may become thicker and more echogenic as it begins to organize. There is a restriction of the late diastolic left ventricular filling and flattening of the epicardial side of the left ventricular myocardium with constrictive pericarditis. An atrial systolic notch and early diastolic notch may be detected in the interventricular septum.\textsuperscript{174} Leftward atrial and ventricular septal movement also may occur. Thickening of the parietal pericardium and epicardium are usually present.
Pericardial Drainage and Lavage

Pericardial drainage and lavage is recommended for all horses with an effusion large enough to successfully insert a large bore chest tube into the pericardial space. The amount and type of pericardial fluid present will determine if an indwelling catheter can be placed or whether only a fluid sample can be obtained. Cytology, culture, and sensitivity testing of the fluid should be performed in both situations. The optimal site for the placement of a catheter for pericardiocentesis should be determined echocardiographically but is usually the left 5th intercostal space, above the lateral thoracic vein and below the coronary groove. If possible, a large-bore Argyle chest tube (24–32 French) is placed in the pericardial sac under ultrasonographic guidance (Fig. 35). Repeated drainage, lavage of the pericardial sac with sterile isotonic fluids, and instillation of intrapericardial antimicrobials are possible with this catheter. Intrapericardial corticosteroids have been used successfully in horses when pericardial inflammation persists and culture results are negative.

Significance/Prognosis

The prognosis for horses with pericarditis has improved markedly over the past 40 years. Treatment failure was common, with the risk of constrictive pericarditis developing later, resulting in a guarded to poor prognosis for affected horses. Constrictive pericarditis is an occasional disruption in an otherwise normal rhythm. In normal fit horses, 2° AVB is occasionally detected in the immediate postexercise period. Horses with 2° AVB usually have a slow or low normal resting heart rate (24–30 bpm). The underlying rhythm is regular, with an
occasional pause that is twice the normal diastolic interval. Auscultation of the heart in a quiet area frequently reveals an isolated S4 associated with the periods of 2°AVB. 39 2°AVB is a regularly irregular rhythm.

Electrocardiogram

The ECG reveals an occasional isolated P-wave not followed by a QRS and T-wave (Fig. 36). All QRS and T waves are preceded by a normal P-wave. The underlying rhythm is otherwise regular (sinus rhythm) or there is a slight irregularity in the underlying rhythm (sinus arrhythmia). In the normal horse, there are always at least three conducted complexes (P-QRS-T) before an isolated P wave.

Occasionally, during a continuous 24-hour recording when the heart rate is slow, two P waves may occur in succession before conducted complexes occur (1%). If frequent 2°AVB is detected immediately postexercise, an exercising ECG is used to be sure that they are abolished with exercise.

Significance/Prognosis

Occasional 2°AVB is a normal arrhythmia associated with a high resting vagal tone that disappears with exercise and does not affect performance or life expectancy, unless it occurs more frequently than normal.

High-Grade 2°AVB

High-grade 2°AVB is uncommon but can occur associated with electrolyte abnormalities, infection (viral, bacterial, or fungal), colic, drugs, toxic insults, plant poisonings, hypoxemia, neoplastic infiltration, anesthesia, or sepsis, among others. These etiologies should be ruled out as much as possible before deciding that the horse has primary conduction system disease.

Electrocardiogram

The ECG reveals frequent isolated P-waves not followed by a QRS and T-wave (Fig. 37). All other QRS and T-waves are preceded by a normal P-wave. The underlying rhythm is otherwise regular (sinus rhythm) or there is a slight irregularity in the underlying rhythm (sinus arrhythmia). A myriad of conduction patterns are possible from horses dropping multiple QRS-T complexes in succession (multiple isolated S4s in succession) after conducting only one or two P-QRS-T complexes to the horse conducting one complex (P-QRS-T) and dropping one (isolated P wave; Fig. 37). If frequent 2°AVB is detected at rest, a continuous 24-hour ECG is recommended to characterize the severity of the arrhythmia and an exercising ECG should be performed to determine if they are abolished with exercise. Intravenous atropine should result in a normal 1:1 conduction.

Echocardiogram

An echocardiographic examination is recommended for all horses with high-grade AVB. Although the echocardiogram may be normal, increased myocardial echogenicity with thickening of the myocardium in the region of the AV node has been seen in affected horses.

Significance/Prognosis

Horses with high-grade 2°AVB should not be used by a child rider or in a lesson program. 39 If the high-grade 2°AVB disappears with exercise, this
horse may be used by an informed adult rider.39 Riding horses in which the 2°AVB does not completely disappear during exercise is not recommended. Frequent monitoring of the horse’s heart rate and rhythm is recommended both at rest and during exercise.39 Monitoring the horse’s rhythm at rest can be performed by monitoring the arterial pulse or ausculting the heart with a stethoscope, which most clients can do successfully. However, a smartphone-enabled ECG recording device is useful for obtaining an actual ECG tracing of the rhythm that can then be emailed to the veterinarian for interpretation. During exercise, a heart rate monitor is used to determine if the horse’s heart rate is appropriate for the degree of exercise performed.

Horses that are symptomatic at rest are not safe for ridden or driven work and should be given a guarded prognosis.29 Progression of high-grade 2°AVB to complete (3°AVB) heart block can occur as the conduction system disease advances. With 3°AVB, none of the impulses originating at the sinus node and conducted across the atria are conducted through the AV node to the ventricle. The atrial and ventricular rates are totally independent, with a very slow ventricular rate. The insertion of a temporary transvenous pacemaker is suggested in collapsing horses, but intermittent pacing can be a problem due to the large size of the equine ventricle.188 Implantation of a permanent pacemaker is the treatment of choice for horses with complete AVB.189,190 Permanent pacing is also an option for horses who are symptomatic with advanced 2°AVB.

Horses with high-grade 2°AVB that does not improve with exercise or excitement and horses with complete heart block are at risk for collapse or SCD. Myocardial inflammation or degeneration of the AV nodal tissues has been detected histopathologically in affected horses. Treatment with a course of corticosteroids in decreasing dosages may be effective if myocardial inflammation is present in acute cases. If sedation of a horse with high-grade AVB is necessary, a2 receptor adrenergic agonist drugs should be avoided, if possible. If use of these drugs is desired, atropine should be used prior to their use to see if the heart rate increases appropriately.191,192

Atrial Fibrillation

Atrial fibrillation (AF) is a common arrhythmia in horses, with a prevalence of 0.6–5.3%.193–198 In horses finishing their race, the frequency of paroxysmal AF is 0.029% compared with a prevalence of 1.39% in slow finishing and nonfinishing Thoroughbred racehorses.199 There was a higher frequency of paroxysmal AF in Standardbred racehorses.199,200 Oldenburg and Westphalian breeds, particularly in male horses and in pacers, were slightly more likely to present with AF in one study, but this effect was not strong, whereas Quarter Horses were at low risk of presenting with AF.212 In the older literature, draft horses were more likely to present with AF compared with light breed horses,213 but that was not the case in a more recent hospital-based study.212

Many horses with AF have little or no detectable underlying cardiac disease. Horses with no detectable heart disease have often been referred to as having “lone” AF. This terminology was coined in human medicine long before the pathophysiology of AF was understood. “Lone” AF referred to individuals in which no underlying cardiac disease was found.215 It is likely that “lone” AF may represent AF where the heart disease is below the limit of detection, rather than AF in the absence of underlying cardiac disease, and that microstructural disease or channelopathies are present in these people. It is likely that the similar situation is present in our equine patients. We know that AF induces rapid electrical and contractile remodeling in horses.216 AF is also a common finding in horses with valvular heart disease, particularly MR (most common) and TR, as well as in those with CHF secondary to the severe valvular heart dis-
Although AR was not associated with AF in one large hospital-based study, when horses with AR develop AF, significant left atrial enlargement should be suspected. The left atrial enlargement is usually a sequela to moderate or severe longstanding AR. AF has been reported in a horse with AR due to a flail aortic valve leaflet and MR.

Although postmortem examination of the first horse reported with AF in 1911 revealed no significant myocardial lesions, myocardial fibrosis and vacuolar degeneration were reported in the next series of horses with AF. Visible atrial myocardial disease (patchy or diffuse fibrosis, dilation, thinning, and/or ballooning) was detected in 80% of horses with AF at gross postmortem examination. Varying degrees of fibrosis was the most common lesion detected histopathologically while 24% of horses had myocardial degeneration and round cell infiltration with minimal fibrosis. One-third of the horses with no gross lesions had a small amount of fibrosis detected microscopically. However, in the remaining horses, the histopathological findings were minimal or nonexistent. Valvular lesions (mostly mitral) were common in this group of horses, present in 80%, and, in most, the valvular regurgitation was significant.

Similar findings of atrial myocardial fibrosis have been found in many studies since, with patchy fibrosis and microscopic focal myocardial fibrosis or fibro-fatty infiltration in the atria. Confounding the picture is the fact that similar histopathological findings have also been reported in the atria of horses without AF.

Horses are predisposed to the development of AF due to their high resting vagal tone, large atrial mass, and autonomic imbalance associated with exercise. Horses with atrial enlargement, therefore, are at an increased risk for AF. Although the risk is likely small, it is an important consideration in horses performing in high-intensity athletic events, particularly in the higher risk sports. Transient potassium depletion secondary to the administration of furosemide or excessive sweating is also a known predisposing factor. Hyperthyroidism, although rare, has also been associated with AF in horses receiving Thyro-L or iodine-containing supplements, such as those containing kelp or ground shellfish. Shortening of the effective refractory period, atrial inhomogeneity, and APCs are other predisposing factors for the development of AF. Atrial tachycardia and atrial flutter are precursor arrhythmias for AF. Pulmonary hypertension has been reported as a rare cause of AF in young horses. AF can be induced by rapid atrial pacing and atrial burst pacing with a programmable pulse generator.

Horses with AF usually have normal resting heart rates (28–44 bpm), although the rhythm is irregularly irregular and no S4 is produced. S1 may vary in intensity due to variable length of ventricular filling time and the lack of an atrial contraction. If the resting heart rate in AF exceeds 60 bpm, significant, usually severe, underlying structural heart disease is likely. The intensity of the peripheral arterial pulses is also irregularly irregular. In some horses, the rhythm is more regular and is initially difficult to distinguish from 2:1 AVB because there is a more patterned AV conduction. Pulse deficits may be present, particularly in horses with two conducted beats occurring in rapid succession. If the resting heart rate is elevated, underlying heart disease, sympathetic stimulation due to another concurrent problem, or an accessory (bypass) tract may be present. The heart should be carefully ausculted for murmurs of MR, TR, and, less frequently, AR. These valvular insufficiencies may be present in horses with AF and influence their prognosis. MR and TR murmurs are common findings in horses with AF, with AR murmurs occurring less frequently. In some horses with AF and moderate to severe underlying valvular heart disease, the murmurs of valvular regurgitation can be quite soft and easily missed.

**Electrocardiogram**

The ECG is diagnostic for AF and reveals irregularly irregular R-R intervals, no P-waves, and normal-appearing QRS complexes (Fig. 38). Rapid baseline fibrillation “f” waves are usually present which may be small (fine) or large (coarse). In approximately 10% of horses with AF, QRS complexes of different morphology that may be aberrantly conducted or originating from the ventricle are present at rest.

**Echocardiogram**

The echocardiogram of a horse in AF usually reveals a reduction in left ventricular shortening fraction that improves with cardioversion. The M-mode of the mitral valve lacks the A peak, caused by atrial contraction (the A peak is also lacking in the tricuspid valve as well). Left atrial and left ventricular internal diameters and areas may be increased, as there are many horses presenting with AF that have mild to moderate MR. Similarly, although less common, there may be right atrial and right ventricular enlargement in AF horses with mild to moderate TR.

**Exercise**

Although the cardiac output in horses with AF and no significant underlying cardiac disease is normal at rest, a drop in cardiac output occurs during exercise. The exercising heart rate, which is often 40–60 bpm higher than if the horse was in sinus rhythm, is a major component of the drop in cardiac output during exercise (Fig. 39). Maximal heart rate during exercise to fatigue increased to...
over 300 bpm in horses with chronic induced AF. Their maximal velocity also decreased by 1.56 m/sec (a 12% decrease) compared with when they were in normal sinus rhythm.

VPCs may be detected at rest in horses with AF. Frequent VPCs (69%) or aberrantly conducted complexes and complexes with wide QRS morphology and R on T (33%) occurred in lunging Warmblood horses with AF and in Standardbred racehorses with induced AF exercising to fatigue. These complexes have been detected in other horses during periods of excitement or exercise (Fig. 40). It is unknown whether these complexes are ventricular in origin or are aberrantly conducted. The detection of these complexes is a cause for concern, as it is unknown what risk they pose for triggering more malignant arrhythmias. Differentiation between VPCs and aberrantly conducted complexes is important, but it is not known how to reliably do this in the horse, unless a multiple lead ECG system can be obtained during intense exercise.

Types of AF

Paroxysmal AF

Spontaneous conversion to normal sinus rhythm may occur in horses with paroxysmal AF, usually within
24–48 hours. These horses usually have little or no detectable underlying heart disease and usually have a small left atrium. Recurrence of paroxysmal AF appears to be rare but has been reported. APCs have been reported in horses upon conversion of paroxysmal AF. Paroxysmal AF has also been reported in the newborn foal, possibly associated with high vagal tone, atrial stretch, and hypoxia that occur at the time of parturition.

**Persistent AF**

Persistent AF does not convert to sinus rhythm on its own but needs medical or electrical cardioversion.

**Permanent (Persistent or Longstanding) AF**

Horses with this AF cannot be converted successfully with either pharmacological or electrical cardioversion.

**Management of Horses with AF**

A complete history should be obtained, including all medications and supplements that the horse is receiving. In particular, the use of furosemide, bicarbonate, kelp, or supplements containing shellfish and Thyro-L should be investigated. A complete performance history should also be obtained, looking for any decrease in performance. In racehorses, the duration of AF should be calculated from the last successful race, as the AF could have developed any time for that point forward. Calculating the duration of the AF is much more difficult in sport horses, unless a clear change in their performance occurred. If there is no clear decrease in performance, the AF should be assumed to be longstanding.

Horses with AF and little or no underlying cardiac disease are candidates for conversion to sinus rhythm, if spontaneous conversion does not occur. Although horses can be used successfully for low-level athletic work, cardioversion is recommended in all horses that are used for rigorous athletic performance. If cardioversion is not an option and the horse is intended to be used for performance, an exercising ECG should be performed to be sure that the exercising heart rate remains at 220 bpm or below when working at the desired effort and that no ventricular ectopy, aberrant conduction, or R on T phenomenon are detected.

In horses with a sudden decrease in performance, conversion could be postponed for 24–48 hours to see if spontaneous conversion occurs, particularly if no cardiac disease can be found echocardiographically. A cTnI is suggested in horses with acute onset AF, if the sample can be obtained within the first 24 or 48 hours. Often, the cTnI will be normal, especially when the AF is more longstanding. However, elevations of cTnI do occur in horses with acute onset AF. Further work is needed to determine how much of this elevation is due to the...
tachyarrhythmia versus the presence of active underlying myocardial disease. Performing a basic chemistry panel, including potassium and magnesium and fractional excretion of potassium (particularly in race horses), as well as serum amyloid A (SAA), should be considered.39

Cardioversion
Cardioversion can be performed via pharmacological or transvenous electrical cardioversion (TVEC). TVEC is available at selected institutions and is very successful in horses with AF and no other detectable underlying cardiac disease or in those with mild left atrial enlargement.

Quinidine is the mainstay of pharmacological cardioversion, but other antiarrhythmic drugs have been used successfully, including amiodarone, flecainide (not recommended due to its association with ventricular arrhythmias and death), propafenone, and phenytoin, but none with the same success. An intravenous catheter should be inserted prior to treatment so that rapid venous access is available should severe arrhythmias develop. A continuous ECG should be obtained throughout the entire treatment period to monitor cardiac rhythm and conduction times during treatment.39 Telemetric ECG is used in the horse receiving pharmacological cardioversion for continuous rhythm monitoring. In horses receiving TVEC, the ECG is monitored with the defibrillator ECG, and the anesthesiologists are monitoring the ECG on their equipment.

At this time, quinidine cardioversion and TVEC have similar success rates (>90%).39,244,245 The decision about the type of cardioversion (pharmacological versus TVEC) depends upon a variety of factors, including cost, comorbidities that preclude general anesthesia, severe adverse or toxic reactions to quinidine, rapid response rate in AF, and complex ventricular ectopy, which are contraindications for quinidine cardioversion.39

Quinidine Cardioversion
The duration of the AF prior to treatment and the presence and severity of any underlying cardiac disease are used to determine the ideal quinidine treatment regimen (gluconate versus sulfate and treatment intervals). If the duration of the arrhythmia is recent (<2 weeks) and there is no echocardiographic evidence of underlying cardiac disease, quinidine gluconate should be administered intravenously (Table 2).246 Successful cardioversion of the horse with recent onset AF (<2 weeks) is likely with conversion occurring during quinidine gluconate treatment or within the subsequent 6–18 hours.246 If quinidine gluconate cardioversion is unsuccessful, quinidine sulfate administration could begin the following day. Alternatively, if conversion has not occurred after administering the total dose of quinidine gluconate, a measurement of the plasma quinidine concentration should be performed, if available, to obtain a baseline value to guide quinidine sulfate treatment on the same day. Plasma quinidine concentration 1 hour after the last quinidine gluconate dose is usually less than 2 μg/ml. Quinidine sulfate administration could then begin at 22 mg/kg administered via nasogastric intubation every 2 hours until conversion or until two doses have been administered every 2 hours. Quinidine plasma concentration should then be checked again 1 hour after the second 22 mg/kg dose of quinidine sulfate before administering another dose in 2 hours, as plasma concentrations are likely to be close to 4 μg/ml.

The frequency of quinidine sulfate administration can then be altered as recommended below to achieve conversion without toxicity.

If the AF is of longer duration (>2–4 weeks) and/or there is mild to moderate but not severe underlying cardiac disease, quinidine sulfate should be administered at 22 mg/kg via nasogastric intubation every 2 hours until the horse converts to sinus rhythm, experiences adverse reactions or toxic side effects to quinidine sulfate treatment, or has received four to six treatments at 2-hour intervals.205 The majority of horses with AF tolerate only four treatments every 2 hours before exhibiting adverse reactions or toxic side effects. If no adverse reactions or toxic side effects are experienced by the horse and conversion to sinus rhythm has not occurred after four treatments administered every 2 hours, a plasma quinidine concentration should be determined. This sample should be obtained 1 hour after the fourth treatment, before continuing with the every 2-hour treatment interval. If the plasma quinidine concentration is >4.0 μg/ml (the therapeutic plasma concentration of quinidine, 2–5 μg/ml), treatment intervals should be prolonged to every half-life, approximately every 6 hours.205 If it is not possible to obtain plasma quinidine concentrations at this time, treatment intervals should be prolonged to every 6 hours. Most horses will have a plasma concentration in excess of 4 μg/ml at this time, and continuing treatment with quinidine sulfate every 2 hours is likely to result in toxicity. Treatment intervals should be maintained at every 6 hours until conversion to sinus rhythm occurs, adverse reactions or toxic side effects develop (rare on the every 6-hour treatment interval), or the owner elects to discontinue treatment. If conversion has not occurred by day 2, oral digoxin is helpful in the conversion of some horses that do not convert with quinidine alone (Table 2).39,205,244 However, digoxin should not be administered beyond day 2 without monitoring serum digoxin concentrations. If serum digoxin concentrations exceed 2.5 μg/ml, the interval between the digoxin treatments should be prolonged to once daily or be based on maintaining a serum digoxin concentration of <2.0 ng/ml.205 The administration of digoxin and quinidine together results in rapid elevations of serum digoxin concentrations (nearly double) and the possible development of digoxin toxicity.247,248
Horses with digoxin toxicity may be anorectic, depressed, colicky, and/or have other cardiac arrhythmias.249–252 Horses being treated for AF with quinidine should be monitored carefully for adverse reactions and signs of quinidine toxicity. The detection of any significant adverse reactions or signs of quinidine toxicity should prompt the discontinuation of quinidine administration. Other treatments may be used if the induced problem is serious. The plasma quinidine concentration should be determined if the horse is experiencing adverse reactions or toxic side effects. A plasma concentration >5 μg/ml is consistent with quinidine toxicity.205 The adverse reactions or toxic side effects are primarily cardiovascular, upper respiratory, neurologic, or gastrointestinal.205 Quinidine-induced upper respiratory tract obstruction is a sign of quinidine toxicity.205 If airflow through the external nares decreases significantly,
Quinidine administration should be discontinued and a nasotracheal tube inserted, if needed. Quinidine treatment should be discontinued if the horse exhibits any bizarre behavior, ataxia, or has a seizure, as these signs are indicative of quinidine toxicity. If seizures occur, anticonvulsants may be used until the plasma quinidine concentrations have decreased and the seizures resolve.

Quinidine is very irritating to the gastrointestinal tract. Flatulence is common and occurs in most horses after several doses of quinidine sulfate. Colic is more likely in horses with more than four treatments administered every 2 hours and quinidine administration should be discontinued if colic develops. Analgesics should be administered as needed for abdominal pain. Diarrhea is not associated with quinidine toxicity and usually resolves with discontinuation of quinidine treatment.

The cardiovascular side effects or toxic reactions from quinidine administration include hypotension, decreased cardiac contractility, CHF, prolongation of the QRS duration, rapid AF, ventricular arrhythmias, and sudden death. The QRS duration should be measured from the ECG prior to each planned administration of quinidine and compared with the pretreatment duration. Prolongation of the QRS duration to greater than 25% of the pretreatment QRS duration is an indication of quinidine toxicity and quinidine administration should be discontinued. Rapid AF occurs in some horses being treated with quinidine for AF. This rapid AF is an idiosyncratic reaction not associated with quinidine toxicity and is caused by a sudden release of vagal tone at the AV node. Sustained ventricular response rates >100 bpm should be treated with digoxin before continuing quinidine administration to prevent further deterioration of the cardiac rhythm. Digoxin should be administered intravenously if the heart rate is rapidly increasing and does not rapidly return to normal. Sustained heart rates >200 bpm require immediate therapy to slow the ventricular response rate. Digoxin should be administered intravenously along with NaHCO3 intravenously. If the horse’s heart rate remains elevated, propranolol or another beta blocker should be administered intravenously to help slow the ventricular response rate.

Drug-induced hypotension is often noted during the initial use of quinidine. Hypotension and depression of cardiac contractility may occur in horses during the first few days of quinidine administration. Phenylephrine intravenously has been used to restore blood pressure in horses with severe hypotension associated with quinidine sulfate administration. Diltiazem could also be tried intravenously but must be used with care with concurrent invasive blood pressure monitoring.

If a large number of VPCs, VT, or multifocal ventricular arrhythmias are detected, quinidine administration should cease and plasma electrolyte concentrations and a creatinine concentration determined, along with a plasma quinidine concentration. Ventricular arrhythmias induced by quinidine administration are usually associated with a proarrhythmic effect and are not a sign of quinidine toxicity. If the ventricular arrhythmias persist or if there is rapid VT, multifocal ventricular complexes, or clinical signs associated with these arrhythmias, the intravenous administration of antiarrhythmic drugs should be instituted. Lidocaine is a good first choice treatment for quinidine-induced ventricular arrhythmias (Table 2). Torsade de pointes, a wide VT, is an arrhythmia induced by quinidine administration that is more likely to occur in hypokalemic horses. Intravenous magnesium sulfate, which is the treatment of choice, should be started immediately in horses with quinidine-induced torsade de pointes. Sudden death in horses with AF treated with quinidine is probably associated with the deterioration of rapid supraventricular tachycardia or VT, most likely torsades de pointes, to ventricular fibrillation (VF) or cardiac arrest. The possibility of sudden death occurring underscores the importance of continuous ECG monitoring and rapid treatment of any arrhythmias that do occur.

**Amiodarone.** After quinidine, amiodarone is the drug with the most success in converting equine AF (66%). Side effects of amiodarone include depression, anorexia, hind limb weakness, diarrhea (10–14 day duration), elevated total bilirubin, widening of the QRS complex, and tachycardia. The hind limb weakness disappears within 4–6 hours of discontinuation of the drug. The hind limb weakness and diarrhea developed in horses treated for more than 36 hours. In humans, hepatotoxicity, thyroid, pulmonary, gastrointestinal, ocular, dermatological, epididymal, and peripheral nerve effects have all been reported with chronic amiodarone administration. One horse with amiodarone-induced diarrhea and concurrent Salmonella infection had to be euthanized due to the severity of its clinical signs that developed when it deteriorated (toxemia, dehydration, and laminitis).

Amiodarone has not been associated with any proarrhythmic effects in horses.

**Flecainide.** Although flecainide has been successfully used for the conversion of pacing-induced AF and acute onset AF in horses, many clinicians feel its use is contraindicated due to the development of dangerous ventricular arrhythmias and the risk of SCD. Flecainide’s prolongation of ventricular repolarization may account for its proarrhythmic effect, inducing dangerous ventricular arrhythmias in horses. It also lacks any protective properties for immediate recurrence of AF (IRAF) due to its lack of effects on the atrial refractory period or vulnerability. Although flecainide does decrease atrial fibrillatory rate in induced AF, it was successful only 41% of the time converting horses with acute AF.
cainide was also unsuccessful in converting horses with chronic AF.\textsuperscript{261,263}

**Propafenone.** Successful conversion of AF with propafenone has not been reported in horses, in spite of achieving concentrations in the plasma within what is considered the therapeutic range in humans.\textsuperscript{264} However, the author successfully converted one horse with AF and VT with intravenous propafenone.

**Procainamide.** Intravenous procainamide has successfully converted one newborn foal with AF.\textsuperscript{243} Procainamide administered PO successfully converted one horse that developed VT associated with the initial dose of quinidine sulfate (again by the author).

**Lidocaine.** Although lidocaine has been used successfully in dogs for acute vagally mediated atrial fibrillation, it has not been used in horses to the author’s knowledge.

**Transvenous Electrical Cardioversion**

Without a doubt, TVEC has revolutionized the treatment of AF in horses, providing an option to pharmacological cardioversion. Successful trans-thoracic electrical cardioversion of a horse with AF was reported in 2002 by using a biphasic defibrillator in conjunction with the administration of quinidine gluconate.\textsuperscript{265} More recently, direct current transcutaneous cardioversion with intravenous procainamide was successful converting a 3-month-old foal.\textsuperscript{266} The first successful TVECs were reported in 2003. These TVECs occurred without any concurrent antiarrhythmic therapy.\textsuperscript{267} TVEC has become the standard of care for electrical cardioversion of AF in the horse.\textsuperscript{268–271} The concurrent administration of antiarrhythmic drugs effective against atrial arrhythmias is currently used by some to prevent IRAF following cardioversion. Pretreatment with amiodarone has been used successfully, as has its use during the TVEC procedure, if cardioversion has not occurred\textsuperscript{271} or if IRAF or frequent APCs are detected. Propafenone and sotalol also have been used as a premedication prior to TVEC. TVEC requires specialized equipment and expertise for successful cardioversion to occur and is usually only performed at selected referral centers.\textsuperscript{39}

TVEC is an excellent option for horses with lone AF of any duration and AF associated with mild left atrial enlargement. It is the treatment of choice for horses that had significant adverse reactions to quinidine or with rapid heart rates while in AF, because quinidine is a positive chronotrope and increases the ventricular response rate in horses with AF.\textsuperscript{39} AF horses with rapid ventricular response rates and complex ventricular arrhythmias are also good candidates for TVEC. Contraindications to TVEC include any comorbidities precluding general anesthesia.

TVEC involves the placement of two specialized electrode-containing catheters under echocardiographic guidance, one in the left pulmonary artery and one in the right atrium (Fig. 41). The catheters are sutured in place (Fig. 42) and placed under a sterile bandage. Thoracic radiography following placement of the transvenous electrodes is used by most to check for accurate placement of the electrode-containing cardioversion catheters. Recently, robotic fluoroscopy has been used to check the placement of the cardioversion catheters to ensure optimal electrode location (Fig. 43). The correct positioning of the cardioversion electrodes is easily accomplished with fluoroscopic guidance. Dexmedetomidine has been suggested as the preferred \(\alpha_2\) agonist for sedation prior to general anesthesia because of its cardioprotective and energy-sparing effects on the myocardium and has been used successfully in several cases.\textsuperscript{272} General anesthesia is necessary for the electrocardioversion. Radiographs under general anesthesia have been recommended to check for optimal electrode position.\textsuperscript{267–270} Displacement of either electrode after induction of general anesthesia is possible, necessitating repositioning of the catheter, prior to TVEC. If correct catheter placement cannot be achieved, termination of the cardioversion procedure is necessary and a second attempt can be made at another time.\textsuperscript{271}

Under general anesthesia, a shock timed with the R-wave of the QRS complex is delivered with the defibrillator synchronized to the R-wave (Fig. 44).\textsuperscript{267–271,273,274} Gradually increasing energy levels are used for each timed shock delivery until conversion occurs or a maximal energy dose has been administered.\textsuperscript{267–270} Mechanical ventilation is usually
needed in anesthetized horses.\textsuperscript{274,275} Although an infusion of detomadine may be needed to counteract hypotension during the procedure,\textsuperscript{274,275} the incidence of hypotension is no different than in those undergoing general anesthesia for MRI.\textsuperscript{274} Conversion occurs when the electrical shock disrupts enough of the fibrillating atria to prevent perpetuation of AF. The success of TVEC probably has a lot to do with the location of the transvenous electrodes, positioned so that a significant amount of atrial myocardium lies between them.\textsuperscript{276}

Delivery of the shock must be synchronized with the QRS complex, as there is a significant risk of VF if the delivery of the shock occurs on the T-wave.\textsuperscript{267–269,271,273} Although rare, VF has resulted in the death of horses with AF undergoing TVEC.\textsuperscript{273} Therefore, because most defibrillators are programmed to revert to an unsynchronized mode after shock delivery, it is critical that the operator of the defibrillator remembers to synchronize the defibrillator prior to each shock delivery, avoiding accidental delivery of the shock synchronous with the T-wave.

Alternatively, the defibrillator should be reprogrammed so that this does not occur.\textsuperscript{273} Transient complete AVB has also occurred following TVEC by using a monophasic electrical defibrillator, necessitating temporary transvenous pacing.\textsuperscript{277}

IRAF is more likely following TVEC than with quinidine cardioversion, prompting some to administer antiarrhythmic drugs in conjunction with TVEC, either before, during, or after the procedure.\textsuperscript{39,271} Peri- and postoperative pain relief is recommended with TVEC\textsuperscript{275} and is usually addressed by the administration of flunixin meglu-

mine. Monitoring of cTnI following cardioversion is recommended but the increase in cTnI that occurs post-TVEC is unlikely to be clinically significant.\textsuperscript{278} Other complications of the TVEC procedure include complications from general anesthesia (postanesthetic myopathy,\textsuperscript{274} facial nerve paralysis,\textsuperscript{274} trauma during recovery, and corneal abrasion). Difficulty removing the electrode catheter has occurred due to reuse of the TVEC catheters, necessitating a venous cut down in one horse in the author’s practice. The failure of the catheters to deliver the shock has also occurred, necessitating replacement of the TVEC catheter. Thrombophlebitis associated with the catheter placement has also occurred.\textsuperscript{274}

Management Postconversion
A follow-up echocardiogram is recommended post-cardioversion to evaluate myocardial function.\textsuperscript{39,279,280} After conversion, atrial contractile function improves.\textsuperscript{280} The left ventricular systolic function also improves following cardioversion,\textsuperscript{136} with an increase in cardiac index and stroke index reported following TVEC.\textsuperscript{275} Atrial systolic dysfunction (atrial stunning) occurs in some horses with a longer than normal time to return to normal function.\textsuperscript{279–281} Although the left ventricular function improves in most horses following cardioversion, in some individuals, the return to normal left ventricular function takes weeks to months. In others, some degree of left ventricular dysfunction persists and the recovery of normal myocardial function may not occur due to the presence of concurrent underlying myocardial disease.
Continuous 24-hour ECG recording is recommended following cardioversion of AF to look for atrial ectopy, because APCs are a risk factor for the recurrence of AF (Fig. 45).\textsuperscript{39,230} If significant atrial ectopy is detected, oral antiarrhythmic therapy should be considered. Numerous antiarrhythmic drugs with efficacy against atrial arrhythmias have been used to try to suppress the atrial ectopy. Currently, sotalol is useful for both its antiarrhythmic and beta-blocking properties. Phenytoin has also been used postcardioversion in two horses; one of which was administered the phenytoin after IRAF occurred following the first quinidine cardioversion.\textsuperscript{282}

The use of an ACE inhibitor may help minimize atrial fibrosis and have a beneficial effect following cardioversion. Oral potassium chloride supplementation should be considered in horses that have low fractional excretion of potassium or are receiving furosemide on a regular basis for EIPH.\textsuperscript{39} If the horse has EIPH, the lowest possible dose of furosemide should be considered. Corticosteroids have also been used if myocardial inflammation is suspected. Thyroid hormone supplementation should be avoided,\textsuperscript{39} as should supplements containing kelp or shellfish.

Horses with recent onset AF, normal left atrial and ventricular function, and no significant atrial ectopy following cardioversion can be returned to training within the week following cardioversion.\textsuperscript{39} A withholding of 2 weeks is recommended following quinidine cardioversion before the horse competes in a sanctioned race or event. Four weeks of rest is recommended in horses with left atrial systolic dysfunction to allow left atrial function to return to normal.\textsuperscript{39} Similarly, a rest period is recommended in horses with persistent left ventricular dysfunction, which should return to normal within 3 days of conversion.\textsuperscript{136} Horses with significant atrial ectopy...
should also rest, with hopes that the APCs will resolve with time and/or antiarrhythmic and anti-inflammatory medication.

Prognosis for Horses Postcardioversion
Patient factors and owner’s expectations, postconversion ECG, and echocardiographic findings must be considered together when formulating a prognosis for horses with AF. In horses with no other structural heart disease, their performance should return to normal once they have returned to normal sinus rhythm.194,205,206,263

The recurrence of AF is independent of the method of cardioversion, with the exception of the increased risk of IRAF following TVEC.39 Recurrences of AF are most likely within the first year following cardioversion, with the most occurring within the first 4 months.194 Recurrence of AF can occur at any time, however. Horses with short duration AF and no evidence of underlying cardiac disease have a recurrence rate of 15%.194,265 This finding is in line with the rapid reverse remodeling following the termination of short duration, experimentally induced AF in horses.216,271 Horses with longer duration AF have a higher risk of recurrence (40% or more).194

Increasing AF duration is correlated with shortening of the minimum AF cycle length.284 AF cycle length is an index of the atrial effective refractory period; therefore, shortening of the minimum AF cycle length is an indication of increased susceptibility to recurrent AF. The ratio of the minimum AF cycle length corrected for left atrial size is correlated with AF recurrence.284 Left atrial enlargement has also been associated with an increased recurrence of AF in numerous studies.284 Even horses with mild MR are at increased risk of experiencing a recurrence of AF.279

Although left atrial contractile dysfunction is associated with early recurrence in humans, this has not yet been demonstrated in horses.279 Only a low active left atrial fractional area change has been associated with recurrence in a multicenter retrospective study of horses with AF.279 Horses with a previous episode of AF or a previous failed treatment attempt are at increased risk of experiencing AF again.279,285 The presence of numerous APCs postcardioversion is likely to increase the risk of AF recurrence.

Treatment for Recurrent AF
Horses with recurrent AF often continue to respond successfully to quinidine cardioversion or TVEC. However, AF is likely to continue to recur, prompting the desire to have a more permanent solution. Although ablation of AF is the treatment of choice for recurrent AF in humans, electrophysiological mapping is necessary to identify the origin of the arrhythmia, usually near the pulmonary veins in humans. Recently, a show jumper with a history of recurrent AF underwent successful ablation of the arrhythmia at Ghent University by Professor Gunther van Loon and his colleagues.

Rate Control for Horses with Permanent AF
For horses with longstanding, persistent (permanent) AF or in horses in which cardioversion is not an option, rate control is an option. For horses that are to be ridden or driven, an exercising ECG is essential to be sure there is no ventricular ectopy, aberrant conduction, R on T complexes, or excessively high heart rate. Horses with AF are usually able to perform successfully if their exercising heart rate remains below 220 bpm when they are performing maximally in their discipline.39 Ideally, the exercise test should be slightly more rigorous than the horse’s normal work. An exercising ECG is also recommended during collection of a breeding stallion with AF to be sure that no ventricular ectopy, aberrant conduction, R on T complexes, or excessively high heart rate develops that might place the stallion or handler at risk. Digoxin can be used to slow the heart rate in horses with rapid ventricular response rates in AF, both at rest and during exercise. Similarly, sotalol has also been used to slow the heart rate in horses with AF.286 Sotalol is also a good choice for slowing rate and suppressing ventricular ectopy in AF horses with ventricular ectopy, aberrant conduction, or R on T complexes. Frequent ECG monitoring of horses on rate control is recommended with 24-hour continuous ECGs and/or exercising ECGs, as dictated by the other comorbidities in the case.

AF with CHF
CHF develops in horses with AF secondary to severe underlying myocardial disease, valvular regurgitation, or congenital heart disease. Those with compensated CHF are inappropriate patients for conversion.39,194,230 Their resting heart rates are elevated (≥60 bpm) and may exceed 100 bpm.38,194 Clinical signs of left-sided heart failure and/or right-sided heart failure may be present.38,206 Although horses with severe acute left-sided CHF can present with frothy nasal discharge that represents the pulmonary edema (Fig. 45), most often the signs of significant left-sided heart disease are more subtle and consist of tachypnea, prolonged recovery to resting respiratory rate, flared nostril, and cough. Many times, veterinary attention is not sought until signs of right-sided CHF (Fig. 46) are present, including generalized venous distention, jugular pulsations, and peripheral edema (pectoral, ventral, preputial, and, less frequently, limb edema). Murmurs of TR and MR are usually present, but other murmurs may be present as well, depending on the underlying cause of the CHF.38,206 In some horses, murmurs that were previously very loud have decreased markedly in intensity, or even disappeared, due to marked elevations of intracardiac pressures. Treatment of horses with CHF and AF should be directed toward slowing the ventricular response rate (heart rate) and supporting
the failing myocardium, not converting the AF (Table 2). 39

Atrial Premature Complexes
Premature beats interrupting an otherwise regular rhythm are most consistent with APCs. APCs usually reset the sinus node so that the underlying rhythm following the premature complex is the same as before the premature complex and a compensatory pause is absent. Although a compensatory pause can occasionally follow an APC, when a premature complex is followed by a compensatory pause, these are more likely to be ventricular in origin. APCs can develop secondary to electrolyte, metabolic, or autonomic imbalances; toxins; drugs; envenomation; overexertion; anesthesia; hypoxia; and sepsis; therefore, these should be ruled out before determining that the horse probably has primary atrial myocardial disease or atrial myocardial disease secondary to atrial enlargement.

An electrocardiogram is needed to confirm the origin (atrial or ventricular) of premature complexes. The APC has a premature P-wave (Fig. 47) that can be conducted with a variable P-R interval or blocked at the AV node. When APCs occur very early in the cardiac cycle, they are buried in the preceding QRS complex and not conducted through to the ventricle, resulting in an irregular rhythm (Fig. 48). These nonconducted APCs are more difficult to identify electrocardiographically and should be suspected when there is a bifid T-wave (P plus T) and a longer than expected pause in the rhythm. The conducted QRS usually has a normal or near normal morphology (Fig. 47), although changes in the QRS and T complex do occur associated with the APC (Fig. 49). Most often, the QRS complex of the APC has an rS morphology in a modified base-apex lead with an increased amplitude rS complex and increased T-wave amplitude. The P-wave of the APC is most commonly a monophasic positive P-wave that is shorter in duration, often with a monophasic and positive T-wave. As the coupling interval shortens, the rS complex tends to become larger. Occasionally, aberrant ventricular conduction can occur, resulting in wider, taller, or bizarre QRS and T complexes.

An exercising ECG is usually recommended, if the horse is otherwise healthy, and secondary causes of APCs have been ruled out to determine their presence and frequency during exercise.

Occasional APCs have been detected during exercise in horses performing successfully in all types of competition. They have also been detected infrequently during exercise in poorly performing horses. APCs are commonly detected in the immediate postexercise (recovery) period.
APCs are usually well tolerated in horses and are often overdriven during exercise. Horses with occasional APCs that are overdriven with exercise are considered safe to ride. Horses with APCs that are infrequent during exercise are also safe to ride in athletic competition. Therefore, if the horse presented for poor performance and the exercise test accurately reflected the work normally performed by the horse, these exercising APCs are unlikely to be affecting performance. When frequent, however, APCs are a risk factor for AF (see Fig. 50). Therefore, the risk of frequent APCs during exercise possibly triggering an episode of AF needs to be considered in sports that are high risk, such as upper-level eventing and racing over fences. Although the risk for AF developing in these horses is unknown and is likely very small, when APCs occur frequently during exercise, it is likely that the risk for AF during exercise is increased.

Atrial Tachycardia/Atrial Flutter

Atrial tachycardia and atrial flutter are uncommon arrhythmias in the horse. Exercise or excitement increases the number of impulses conducted through the AV node and patterned conduction occurs. There is the risk of rapid tachycardia with 1:1 conduction that can lead to collapse or tachycardia-induced CHF. Sustained atrial tachycardia and atrial flutter are difficult to differentiate with a surface ECG. Many impulses are blocked at the AV node, resulting in an irregular rhythm, similar to AF. Although atrial tachycardia or atrial flutter can develop secondary to autonomic, electrolyte, or metabolic imbalances; toxins; drugs; envenomation; overexertion; anesthesia; hypoxia; and sepsis; underlying myocardial disease may be more likely. Structural heart disease is likely in horses with atrial tachycardia that persists for one week or more or in horses with recurrent atrial tachycardia or atrial flutter. A cTnI should be performed to look for active myocardial injury.

Atrial tachycardia and atrial flutter may precede the development of AF. Atrial flutter or atrial
Tachycardia can also persist after attempted conversion of atrial fibrillation to sinus rhythm. An accessory pathway, although rare, should also be considered in these horses.

The ECG reveals a rapid atrial rate with regularly appearing P-waves, normal-appearing QRS and T complexes, and numerous periods of 2°AVB (Fig. 51). Although accurate differentiation is not possible without intracardiac electrocardiography, the atrial activity with atrial flutter classically has a saw tooth appearance (Fig. 52) rather than the more rounded appearance of a P-wave seen in atrial tachycardia with 2°AVB. There is classically an isoelectric period between the P-waves in horses with atrial tachycardia that is lacking with atrial flutter. Atrial rates usually vary between 150–250 depolarizations/minute.

Cardioversion of affected horses with TVEC is the preferred treatment due to the risk of 1:1 conduction of the atrial depolarization to the ventricle with the use of quinidine. Postconversion management should be similar to that for horses with AF. Continuous 24 hour ECG recording should be performed to look for atrial ectopy. The recurrence rate of atrial tachycardia/atrial flutter in horses is unknown but recurrences have happened in affected horses. In horses with persistent atrial tachycardia/atrial flutter, there is the potential risk of 1:1 conduction, with exercise resulting in a rapid tachyarrhythmia with heart rates inappropriately high for the work performed and the risk of possible collapse.

Ventricular Premature Complexes

Premature beats followed by a pause interrupting an otherwise regular rhythm are most consistent with VPCs. Often, the S1 associated with the VPC is loud and booming “bruit de cannon.” VPCs can develop secondary to electrolyte, metabolic, or autonomic imbalances; toxins; drugs; poisonous plants; envenomation; overexertion; anesthesia; hypoxia; significant blood loss; and sepsis; therefore, these should be ruled out before determining that the
horse probably has primary myocardial disease involving the ventricle. VPCs associated with underlying medical or surgical problems, drugs, or anesthesia may resolve with the correction of the underlying problem, discontinuation of the drug, or recovery from anesthesia without myocardial injury.

However, some of the underlying problems causing ventricular arrhythmias are associated with myocardial injury. Obtaining a cTnI is useful in the assessment of ongoing myocardial injury and its severity.

VPCs and complex ventricular arrhythmias, including VT, occur in the majority of horses with significant hemorrhage and are associated with an elevation of cTnI. The arrhythmias are likely to be worse in the 24–48 hours following the acute hemorrhage. An elevation of cTnI is likely in all horses with significant acute hemorrhage and is most likely associated with myocardial hypoxia and/or reperfusion injury. Sympathetic stimulation may also contribute to the myocardial injury in these horses. The maximal elevation of cTnI was associated with the need to treat the cardiac arrhythmias detected and with nonsurvival, although cardiac arrhythmias were not the cause of death in these horses with severe hemorrhage.

Colicky horses with an elevation of cTnI are also more likely to have VPCs or VT, most likely associated with endotoxemia, hypoxemia, or sepsis. An elevation of cTnI in horses with colic is associated with a negative outcome. Although VPCs and VT were not seen in horses in one study where an elevated cTnI was significantly associated with a negative outcome, the short ECG monitoring time (1 hour) and the use of a lidocaine infusion may explain this difference. cTnI is positively correlated with hematocrit, heart rate, and lactate. Ventricular arrhythmias have also been detected in experimental endotoxemia, occurring after the peak in the cTnI.

VPCs are characterized by a premature QRS that is typically wide and bizarre and followed by a large T-wave of opposite polarity, without an associated P-wave (Fig. 53). VPCs do not reset the sinus node because there is no retrograde conduction from the ventricle to the atria. The sinus node is unaffected by the VPC, and the P-wave following the VPC is usually not conducted unless the VPC is very early, resulting in an interpolated VPC (a VPC sandwiched between two normal sinus beats). Thus, most VPCs are followed by a compensatory pause. If there are several uniform VPCs in succession, occurring slightly faster than the sinus rate (50–80/minute) at rest, with a relatively long coupling interval, it is likely to be an accelerated idioventricular rhythm or AIVR (Fig. 54)

VPCs are a risk factor for the development of VT. VPCs that are multiform (Fig. 55), occurring on top of the preceding T-wave, known as R on T (Fig. 56), repetitive, or occurring in runs (paroxysmal VT) are complex ventricular arrhythmias and are more likely to be associated with an adverse cardiac event (collapse or SCD).
In horses, the deterioration of the rhythm to VT with significant hypotension. This can further deteriorate into VF, resulting in SCD.

A routine chemistry profile and cTnI is recommended in all horses with frequent or recurrent VPCs. A complete blood count, fibrinogen, and SAA is recommended in all horses with VPCs and fever or a history of fever. A continuous 24-hour ECG is needed to evaluate their frequency, as they are often intermittent. An echocardiogram should be performed for all horses with frequent or recurrent VPCs to look for underlying structural heart disease. This is especially important in horses with complex ventricular arrhythmias or when ventricular arrhythmias are identified in a horse with poor performance, collapse, a loud murmur, or a significant elevation of cTnI. The myocardium should be carefully evaluated for focal or more diffuse changes in echogenicity, thickness, and contractility. In many instances, the echocardiogram will be normal, especially in those with uniform VPCs.

Ventricular Tachycardia

A rapid rhythm with loud booming heart sounds and jugular pulses is characteristic of VT. The rhythm is regular in horses with uniform VT but irregular in horses with multiform VT. Horses with sustained VT can develop CHF secondary to the sustained tachycardia, without having primary underlying cardiac disease. In general, the higher the rate of the VT, the faster the horse develops clinical signs of tachycardia-induced cardiomyopathy and CHF. If the VT is multiform, CHF often occurs more quickly due to the likely presence of significant underlying myocardial disease. A cTnI is recommended in all horses with VT to look for evidence of myocardial damage. Significant elevations of cTnI and cTnT occur associated with rapid VT that quickly return to normal in horses with uniform VT.

VT can occur secondary to electrolyte, metabolic, or autonomic imbalances; toxins; drugs; envenomation;
overexertion; anesthesia; hypoxia; significant blood loss; and sepsis; similar to the situation in horses with VPCs. These should be thoroughly investigated, similar to horses with VPCs, looking for possible reversible causes of VT. However, sustained, recurrent, or multiform VT in horses is often associated with primary myocardial disease involving the ventricle.

A run or a continuous stream of large, rapidly occurring QRS complexes with their T-waves oriented in the opposite direction of the QRS complexes that are not associated with the P-wave is consistent with VT. The atrial rates (P-waves) occur at a slower rate than the QRS and T complexes and are buried in these complexes (Fig. 57). The QRS is usually widened, in addition to appearing bizarre (different from the normal QRS complexes), but narrow QRS complex VT does occur in horses (Fig. 58). A wide VT can also occur (Fig. 59), the most severe of which is torsades de pointes (Fig. 60), when one QRS merges into the next with a sine wave configuration. VT can be uniform (with all the QRS and T complexes looking alike) or multiform (Fig. 57).

An echocardiogram should be performed for all horses with VT to look for evidence of underlying structural heart disease. As with horses with VPCs, the myocardium should be carefully evaluated, looking for echoic areas consistent with fibrofatty infiltrate or a scar that could act as a substrate for reentrant arrhythmias. Changes in myocardial thickness and chamber size should be evaluated, along with evaluation of myocardial function and synergy. Tachycardia-induced cardiomyopathy is a possible development in affected horses. Horses should also be carefully assessed for any aortic root abnormalities (aneurysm, calcification, or rupture), particularly for an ACF, as these horses often present with colic and VT. The cardiac valves, particularly the aortic valve, should be carefully evaluated for any vegetative lesion of bacterial endocarditis. Once the VT has converted to a normal sinus rhythm, the echocardiogram should be repeated regardless of the etiology of the VT. TDI evaluation of myocardial function following conversion may prove to be very
useful in the evaluation of equine myocardial function in horses following an episode of sustained VT.

Paroxysms of VT in horses performing a maximal exercise stress test on the treadmill to fatigue results in their rapid deceleration due to the rapid drop in cardiac output during exercise (Fig. 61). Although an association between complex arrhythmias and poor performance has been made,293 these may coexist in poorly performing horses without being negatively associated with athletic performance.292 Ongoing research by a number of investigators will shed more light on the significance of ventricular arrhythmias during exercise, both on their role in poorly performing horses and hopefully in horses experiencing SCD.

Horses with uniform VT and no evidence of structural heart disease often recover and return to normal work but recurrences can occur.39 These horses should be treated for their arrhythmias, rested for a minimum of 4 weeks, and a cardiac reevaluation performed before returning the horse to work. A continuous 24-hour ECG should also be performed before returning the horse to work, followed by an exercising ECG if the continuous 24-hour ECG is normal.39 A second exercising ECG should be performed once the horse has returned to full work.39 Annual continuous 24-hour ECG monitoring and exercise testing is recommended in these horses, along with echocardiographic reexamination.

Horses with complex ventricular arrhythmias should also be treated for their arrhythmias and rested for 4 weeks before cardiac reevaluation. Often, multiple cardiac reevaluations are necessary before there is a minimal amount of ventricular ectopy at rest. These horses should not be ridden or driven until their rhythm has returned to normal on a continuous 24-hour ECG and then is normal during an exercise test. A second exercise test should also be performed in these horses once the horse is back in full work. Periodic continuous 24-hour ECG monitoring and exercising ECGs of these horses is recommended to look for increased ventricular ectopy (at least annually and with more complex ventricular arrhythmias, at least biannually).

Echocardiographic reexamination should also be performed at least annually in horses with a history of complex ventricular arrhythmias. These horses should only be ridden by an informed adult rider, as their safety is uncertain.39 Horses with AIVR that is overdriven with exercise can be driven or ridden by an informed adult rider.39 Rigorous athletic work is not recommended for horses that have underlying structural heart disease (myocardial fibrosis or moderate to severe AR) and VT, and these horses should only be used by an informed adult rider.39 Annual echocardiographic evaluation, continuous 24-hour ECG monitoring, and exercise testing is recommended in these horses.

8. Sudden Cardiac Death

Sudden death in horses during or shortly after exercise has a myriad of causes.311–313 Massive internal hemorrhage associated with vessel rupture, including aortic rupture, are common cardiovascular causes of sudden death.311–316 Horses that ex-
experienced sudden death with no other causes of death determined at postmortem examination are considered to have experienced SCD due to a fatal ventricular arrhythmia. Some of the horses that experience sudden death have pulmonary edema, congestion, and/or hemorrhage, which may be secondary to cardiovascular causes, although an acute upper respiratory tract obstruction should also be considered. Although EIPH is common in racehorses, its relationship to SCD remains unclear, with only low-quality evidence of an association. Finding myocardial pathology in horses that experience SCD can be challenging due to the large size of the equine heart, so, in many horses, no pathological lesions are found in the myocardium. In addition, small areas of myocardial fibrosis can be found in horses euthanized for other reasons and have no clinical significance. Small areas of myocardial fibrosis were present in 14.3% of slaughtered horses thought to be ischemic in origin. Myocardial ischemic and fibrotic lesions have been found in tissue close to the sinoatrial and AV node in horses that experienced SCD, similar to findings in humans that experienced SCD. Other causes of SCD include widespread myocardial diseases, diseases of the aorta and aortic root, pulmonary artery diseases, and, occasionally, other cardiac arrhythmias. SCD usually occurs during or shortly after training, racing, or other forms of exertion and has come into sharper focus due to the high visibility of horse and rider deaths in equestrian sports. Arrhythmias are commonly detected in horses immediately postexercise, and, less frequently, during exercise, most of which are clinically insignificant. Complex ventricular arrhythmias were detected in 16% of Standardbred racehorses during cardiac deceleration, associated with large shifts in autonomic tone at the completion of a race. These were often associated with sudden rapid increase in vagal tone. Although there were no instances of SCD in this study, the detection of these in the immediate postrace period is compatible
with the timing of many SCD cases in exercising horses, suggesting that large fluctuations in autonomic tone may play a role in these cases. Occasionally, ECGs obtained during the period immediately preceding SCD reveal VT, R on T complexes, wide VT, or torsade de pointes that degenerate into VF. In most instances, however, the diagnosis is a diagnosis of exclusion at the time of postmortem examination.

Severe bradyarrhythmias and tachyarrhythmias can cause collapse and SCD in horses. This is reported most frequently in young racehorses that are often found dead or collapse and die suddenly. At postmortem examination, there may be myocardial lesions or cardiac disease is presumptive, with no other cause of death detected. On occasion, VT is documented in the minutes or hours prior to death. Multifocal myocardial necrosis or fibrosis
has been documented histopathologically in some of these horses. These lesions were found close to the sinoatrial node, in the AV junction, and in the upper portion of the interventricular septum in one study, along with vascular changes. Myocarditis, myocardial necrosis, fibrosis, and fatty and fibrofatty infiltrates can cause SCD via triggering of fatal ventricular arrhythmias. Fibrous, fatty, or fibrofatty infiltrates in the myocardium have been found in horses of all ages with fatal ventricular arrhythmias/SCD and may be similar to changes seen with arrhythmogenic cardiomyopathy in humans.\textsuperscript{108–110} Arrhythmogenic right ventricular cardiomyopathy has caused SCD in several horses.\textsuperscript{108–110}

Profound sinus bradycardia, long periods of sinoatrial arrest, sick sinus syndrome, high-grade 2°AVB, and 3°AVB are frequently associated with underlying myocardial disease. These arrhythmias can cause poor performance, exercise intolerance, collapse, or SCD.\textsuperscript{108,190,324–326}

### 9. Congestive Heart Failure

Valvular regurgitation is the most frequent cause of CHF, with MR being the most common cause.\textsuperscript{327} Congenital cardiac disease, cardiomyopathy (nutritional, ionophores, toxins, and plants), ACF, aortic pulmonary fistulation, tachyarrhythmias (usually ventricular), pericarditis, hypertension, chronic renal disease, and cor pulmonale can all lead to a horse presenting in CHF.

Fortunately, CHF is uncommon, representing 10.5% of horses brought into one teaching hospital for cardiac evaluation.\textsuperscript{327} These horses had an average age of 8.5 years. Tachycardia (mean of 62 bpm) and loud (grade 3/6 or louder) heart murmurs were present in all horses, with AF being the most common arrhythmia detected.\textsuperscript{327} Jugular distention and pulsation was common, with the majority of horses also having crackles, a cough, and tachypnea (mean, 28 breaths/minute). Half of these horses presented with ventral edema. Hypoxemia was present in all horses in which a blood gas was performed.\textsuperscript{327}

Although horses with severe MR first develop signs of left-sided CHF, these signs often go undetected, resulting in the majority of horses with chronic MR presenting with clinical signs of right-sided CHF.\textsuperscript{327,327,328} The signs of left-sided CHF in horses with chronic MR are an elevated respiratory rate (93%) and respiratory effort and cough (42%), which often goes unnoticed or is attributed to lower airway disease.\textsuperscript{328} Coarse bronchovesicular sounds are common (91%), with crackles auscultable in nearly half (49%) of horses.\textsuperscript{328} Jugular venous distention, jugular pulsations (62.8%), ventral edema (42%), tachycardia (93% had heart rates of ≥60 bpm), and AF (58%) are frequently detected. An accentuated S3 is also common (49%).\textsuperscript{328} It is important to recognize that in horses with murmurs of TR and MR and clinical signs of right-sided CHF, the primary disease is left-sided valvular insufficiency, not right. When MR is longstanding and gradually increases in severity, there is time for left atrial volume and left atrial compliance to gradually increase.\textsuperscript{328} Chronically elevated pulmonary venous pressures lead to pulmonary arteriolar vasoconstriction and hypertension with increased right ventricular afterload, resulting in the clinical signs of right-sided CHF.\textsuperscript{327} Horses with acute left-sided CHF and frank pulmonary edema emanating from their nares only represented 16% of those presenting with MR and CHF.\textsuperscript{328} This is usually secondary to a RCT,\textsuperscript{327} resulting in rapid onset severe MR and CHF.\textsuperscript{48,53,54} Most horses presenting with left-sided CHF have a RCT involving the septal leaflet of the mitral valve, whereas most horses with biventricular failure have a RCT involving one of the accessory leaflets of the mitral valve, usually the caudal accessory leaflet, or chronic degenerative mitral valve disease. Right-sided CHF alone is uncommon but occurs with some congenital defects and severe TR.\textsuperscript{327} Right-sided CHF is also seen in some horses with ACFs. Recurrent airway obstruction and severe pulmonary hypertension have also been infrequent causes of CHF.\textsuperscript{327,327,330} Pulmonic valve rupture also resulted in right-sided CHF in one horse.\textsuperscript{331}

Echocardiography is extremely useful in the diagnosis of the underlying cardiac disease causing CHF.\textsuperscript{183,327} Sonographic evaluation of the lungs reveals the presence of B-lines or “lung rockets” (previously referred to as comet tail artifacts) throughout, becoming more numerous and confluent as the severity of pulmonary edema increases.\textsuperscript{183} In dogs with CHF, the location of the B-lines corresponds to the location of pulmonary edema detected on thoracic radiographs.\textsuperscript{332} Thoracic ultrasonography can be easily performed in the field and should be included as part of the initial evaluation of a horse with CHF. Radiographs are also helpful in identifying pulmonary edema, which typically appears as a diffuse interstitial or bronchointerstitial pattern.\textsuperscript{327} Cardiomegaly is also frequently detected on thoracic radiographs of horses with CHF.\textsuperscript{327}

Treatment for CHF includes diuretics to reduce preload, afterload reducers, and a positive inotropic drug.\textsuperscript{327,333} Pulmonary edema is life threatening, so it should be treated promptly and aggressively. Furosemide can be administered intravenously as a bolus and repeated in 30–60 minutes to treat fulminating heart failure and then administered as needed. However, an intravenous loading dose of furosemide followed by a furosemide constant rate infusion (CRI) is superior to furosemide administered at 1 mg/kg every 8 hours when profound diuresis is needed (Table 2).\textsuperscript{334} Intravenous, intramuscular, or subcutaneous administration of furosemide is recommended in horses with CHF due to the poor bioavailability of oral furosemide.\textsuperscript{334} The advent of torsemide, a newer stronger loop diuretic with a longer half-life and higher bioavailability in other
species, 335–337 may be an attractive alternative to furosemide when it is no longer very effective.

Hydrochlorothiazide can be added to promote additional diuresis, if needed. Both electrolytes and renal function should be monitored in horses on diuretics. High-quality hay, such as alfalfa, rich in potassium, should be fed and oral potassium supplementation should be considered for horses requiring long-term treatment with furosemide. KCl salt is not very palatable and must be gradually introduced into the horse’s grain.

Vasodilators are a very important part of the treatment of CHF. 333 ACE inhibitors are mixed vasodilators that have been shown to decrease the left ventricular internal diameter in systole, increase fractional shortening, and improve cardiac output in horses with MR or AR. 52 ACE inhibitors should be administered in horses with CHF to improve afterload.

Digoxin, 43, 44, 327, 333 has been the drug of choice, unless the horse presents in severe acute CHF. 249 In these horses, intravenous dobutamine or intravenous digoxin is suggested with furosemide. 333, 338 The dose of digoxin should be modified (decrease dosing intervals to q 24 h or decrease dose) if prerenal azotemia is present. With the availability of pimobendan, this may change, as this drug is now widely used for the treatment of acute and chronic CHF in dogs and humans. 333, 339 Although the optimal dosage of pimobendan remains to be determined, as does its efficacy in horses with CHF, it is likely to have a beneficial effect on cardiovascular function in horses with CHF, particularly when given via intravenous administration. 339

Serum or plasma samples should be obtained for therapeutic monitoring of digoxin concentrations after several days of oral therapy to see if adjustments in the dosage are necessary. 333 Peak (sample obtained 1–2 hours after oral digoxin administration) and trough digoxin concentrations should be obtained; the therapeutic range of digoxin is 0.5–2 ng/ml. 249 Clinical improvement usually occurs with this treatment regime within 48 hours. 249 However, the improvement is usually of short duration (2–6 months). Digoxin toxicity has been reported in horses with digoxin concentrations >2 ng/ml. 249 Anorexia, lethargy, colic, blindness, 340 and the development of other cardiac arrhythmias have all been reported in horses with digoxin toxicity. 262, 338 Hypokalemia potentiates the toxic effects of digoxin; therefore, careful monitoring of the horse’s potassium status is important. The administration of digoxin should be discontinued in all horses when digoxin toxicity is suspected and a blood sample obtained for serum or plasma digoxin, potassium, and creatinine concentrations. A lidocaine CRI is recommended for the treatment of ventricular arrhythmias associated with digoxin toxicity (Table 2). 338 Phenytoin may be used in the treatment of supraventricular arrhythmias associated with digoxin toxicity. 252

In general, the prognosis for horses with CHF is considered grave. 38, 206, 327 Horses are generally euthanized or die within a year following the diagnosis of CHF. 327

10. Cardiovascular Prepurchase Examination

History

Obtaining an accurate history is an important part of a prepurchase examination, although in some instances, the horse’s prior history is not available.

If disclosed that the horse has a history of cardiac disease, information about the cardiac disease diagnosed, the results of tests performed, and any treatment the horse received should be requested.

Cardiac Examination

Auscultation of the heart is a critical part of the equine prepurchase examination, both at rest and postexercise in a horse being used for performance. Knowledge of what is normal on the resting and postexercise cardiac examination is critically important in this setting. Understanding the significance of arrhythmias and murmurs ausculted is important for making recommendations about their importance in the prepurchase setting or for deciding when referral to a specialist for further evaluation is needed. Any adult horse with a continuous murmur is likely to have severe underlying cardiac disease and not be a candidate for purchase.

Arrhythmias associated with high resting vagal tone (2°AVB, sinus arrhythmia, and sinoatrial block) should disappear with exercise or excitement and the horse should have a regular cardiac rhythm. If a vagally mediated arrhythmia is detected immediately postexercise, an exercising ECG is recommended to determine if they disappear during exercise. Any premature beats or other irregular rhythm that is ausculted in a prepurchase setting should be clarified with a resting and continuous 24-hour ECG, as well as an exercising ECG to determine their frequency and significance during exercise.

An echocardiographic examination should be performed for all horses with a grade 3/6 or louder mid to late crescendo murmur loudest on the left side of the chest, a grade 3/6 or louder holosystolic or pansystolic murmur loudest on the left or right side of the chest, or any holodiastolic murmur that are being considered for purchase to identify the etiology of the murmur. Determining the severity of the underlying structural heart disease is critical for assessing its impact on the horse’s future performance and life expectancy, as previously discussed. In particular, left atrial enlargement is a risk factor for the development of AF and is an important consideration for horses competing in high-intensity athletic events.

Arrhythmias. The prospective buyer should be aware that a horse with a history of sustained AF (single episode) has a 40% chance of experiencing a recurrence, unless the AF was recent in onset and no
If there is a history of VPCs or AIVR or they are detected during the prepurchase examination, an echocardiogram, continuous 24-hour ECG, and exercising ECG should be performed prior to purchase. If the VPCs or AIVR are overdriven during exercise, they should not affect performance, but these horses are still not considered suitable for a child rider or for a lesson program. However, horses with APCs or a history of APCs that are overdriven during exercise or are infrequent during exercise should not experience performance problems, unless one of the APCs triggers an episode of AF. These horses are considered to be as safe to ride as one of their age-matched peers. However, if the APCs are more frequent, the risk for AF may be higher and this must be factored into the purchase decision for a horse competing in his intensity athletic events.

**Regurgitant Murmurs.** If the horse has a significant murmur or a history of valvular regurgitation, an echocardiographic examination or reexamination should be performed. If the horse has TR, the horse should have a good prognosis for performance and life expectancy, unless the TR is severe or the horse has significant right ventricular dysfunction. With severe TR, the horse is unlikely to perform at the top level in high intensity athletic events, but the horse’s life expectancy should be normal unless there is significant right ventricular dysfunction. If the horse has MVP, the horse should also have a good prognosis for performance and life expectancy, unless there is moderate or severe regurgitation. If left atrial enlargement is present, there is concern that the horse will have an increased risk for AF, a factor that is important to consider in horses expected to compete in high-intensity sports. The MR in horses with degenerative valve disease, RCT, or flail mitral valve leaflet is more likely to progress. An exercising ECG is recommended as part of the prepurchase examination in these horses. These horses may have a shortened performance life and life expectancy that prospective purchasers need to be informed of.

Horses with AR that is mild and associated with degenerative valve changes are likely to have a normal performance life and life expectancy if they are middle aged when the prepurchase examination is performed. If the AR is moderate or severe, however, performance problems may develop in the next several years and safety problems may also be a concern, associated with the risk for the development of VAs. These horses are not suitable for purchase for a child rider or a lesson program due to these risks. Horses with moderate or severe AR may be suitable for an informed adult rider competing in less rigorous disciplines, being used as a schoolmaster, or for pleasure riding. These horses also need an exercising ECG as part of their prepurchase examination, along with a continuous 24-hour ECG to look for ventricular ectopy.
purchasers should be informed that these horses may have a shortened life expectancy and that annual or biannual (when AR is more severe) reexaminations should be performed to ensure the safety of the horse and rider.

Horses with a history of bacterial endocarditis should have a complete echocardiographic examination performed if they are being considered for purchase, along with a continuous 24-hour ECG and an exercising ECG. Even when a bacteriologic cure is obtained, affected valve leaflets continued to scar as part of the healing process. This scarring occurs over a period of months to years and often leads to a worsening of the valvular regurgitation. Although this is very well tolerated if the vegetative endocarditis involves the tricuspid valve, with significant involvement of the mitral or aortic valves, severe regurgitation often ensues leading to the development of CHF.

VSD. Horses with small VSDs should have a normal performance life and life expectancy but are not likely to perform at the top level in high-intensity disciplines (e.g., racing and eventing). The prospective purchaser should be informed that these horses are likely to develop MR as they age, due to the chronic left ventricular volume overload. With small VSDs, CHF is unlikely, but it is a risk for horses with moderate-sized VSDs or with VSDs that are hemodynamically restrictive but are anatomically moderate or large sized with AVP. All horses with a history of a VSD should have an echocardiogram performed.

Myocardial Disease. All horses with a history of myocardial disease should have an echocardiogram repeated as a part of the prepurchase examination, along with a 24-hour ECG and an exercising ECG. If these examinations are normal, horses with this history are likely to have a normal performance life and life expectancy in the absence of a history or severe ventricular arrhythmias.

11. Summary

It is an exciting time in equine cardiology. The knowledge of cardiac problems affecting horses is growing rapidly, as are the technological advancements, enabling an accurate diagnosis and assessment of severity. Equine cardiac research is ongoing, investigating a variety of problems, including rhythm disturbances, valvular insufficiencies, and myocardial disease, among others. Pharmacological studies are giving us new drugs and protocols for use in the management of horses with cardiac disease. Studies of exercising horses are giving us new information about what is normal in horses performing up to expectations, as well as in poorly performing horses. These advancements will continue to advance our understanding of the equine heart in health and disease, helping us to find a balance between performance and safety that benefits the horse, the various performance disciplines, and the rider or driver.

Videos can be viewed at the following links:

- Flail Mitral Valve: https://www.youtube.com/watch?v=HgvUv8i0HESs&feature=youtu.be
- Severe MR with AF: https://www.youtube.com/watch?v=0YPb1Y3reqe&feature=youtu.be
- Large MR Jet: https://www.youtube.com/embed/f_npPvsWCdo
- Vibrating Aortic Valve: https://www.youtube.com/watch?v=zl7Bld9q4&feature=youtu.be
- Aortic Regurgitation Jet: https://www.youtube.com/watch?v=o3DJK0_YL8o&feature=youtu.be
- VSD: https://www.youtube.com/watch?v=qal725l8DjI&feature=youtu.be
- VSD Color Jet: https://www.youtube.com/watch?v=1A0oiYC5Qzs&feature=youtu.be
- Aortocardiatic Fistula: https://www.youtube.com/watch?v=epVJDPA9q90&feature=youtu.be
- LV Dysfunction: https://www.youtube.com/embed/iTty0OX80Bg
- LV Scar: https://www.youtube.com/embed/Kp1ChJk3S6o

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnote


A workplace free of damaging behaviors has consistently been shown to increase workforce productivity, reduce on-the-job errors, reduce employee turnover, and create happier clients. Unaddressed workplace issues are a major reason for associate veterinarians to consider finding another position. Author’s address: Wimberley Veterinary Clinic, 12605 Ranch Road 12, Wimberley, TX 78676; e-mail: tracysheff@gmail.com. © 2018 AAEP.

1. Introduction

The veterinary workplace environment is overlooked at the peril of business profitability. Practice owners want to focus on veterinary medicine, not business management. Neglecting business management, specifically issues related to the workplace environment, has hidden costs to the business.

A lack of understanding of the true costs of an unmanaged work environment leads practice owners to choose inaction as the most expedient answer to difficult workplace situations. Inaction can be the worst response when faced with a workplace issue. Inaction can frustrate associates to the point that they leave a practice where they enjoyed practicing quality medicine but found the work environment too toxic to tolerate any longer.

Adopting and enforcing behavior expectations for all staff members and creating a civil, professional, and safe work environment improves the bottom line in any business setting.

Veterinarians seeking associate positions would be well advised to evaluate the workplace environment before deciding to accept a position. A toxic work environment leads many associates to leave a position even though they appreciate other facets of their employment.

A survey of workplace environment issues found that the veterinary profession has much room for improvement. Changes to improve a work environment are reasonably easy to implement, do not require an outlay of cash, and have a direct impact on improving volume and quality of work produced.

2. Methods and Materials

Participants

Responses from came from 205 veterinarians, of whom 87.8% (n = 180) were female and 12.2% (n = 25) were male. Of these 205, 191 completed the full survey. Sixty-four respondents (33.51%) have been in practice less than 2 years; 45.03% (n = 86) have been in practice 2 to 5 years; 13.09% (n = 25) have been in practice 6 to 15 years; and 8.38% (n = 16) have been in practice greater than 15 years.

Survey

A nine-question, anonymous survey was made available on various veterinary-only social media platforms and by direct e-mail to Texas Veterinary
Medical Association members. The direct e-mail recipients received selection bias based on the year graduated. Part of the purpose of the survey was to determine management response to issues. As recent graduates and relatively new hires are more likely to be subordinate to management rather than in management themselves, this puts them in the position to evaluate management rather than evaluating their own management skills.

3. Results

The survey found that veterinarians support their colleagues. Overwhelmingly, they support other doctors through complex or unusual cases. This part of the workplace environment is where veterinary medicine really gets it right.

Medical Experiences

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<th>Answer Choices</th>
<th>Responses</th>
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<tbody>
<tr>
<td>With complex medical cases all doctors on staff assist as they are asked and as they are able</td>
<td>80.10%</td>
</tr>
<tr>
<td>I am generally left on my own to work up complex or unusual cases</td>
<td>16.23%</td>
</tr>
<tr>
<td>I am seldom given the opportunity to work up major medical cases</td>
<td>1.57%</td>
</tr>
<tr>
<td>I have had cases taken away from me with no explanation</td>
<td>2.09%</td>
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The veterinary workplace does not fare as well when discussing the work environment. It would appear that veterinarians want to be veterinarians, not business or human resource managers. The default response of management is to take no action at all. The survey found that management took no action when issues were brought to their attention over 50% of the time. Inaction itself takes varying forms, from listening to complaints and simply not doing anything to outright hostility.

In My Experience, Management

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<tr>
<th>Answer Choices</th>
<th>Responses</th>
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<tr>
<td>Is responsive to issues and takes appropriate action</td>
<td>45.55%</td>
</tr>
<tr>
<td>I can go to management but no action is actually taken</td>
<td>36.65%</td>
</tr>
<tr>
<td>Is not interested in taking on anything pointed out to them</td>
<td>12.57%</td>
</tr>
<tr>
<td>Is openly hostile when they are made aware of issues</td>
<td>5.24%</td>
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Professional courtesy and respect are important components of the workplace environment. The survey shows that, while generally doing well in this area, there is room for improvement.

In the past and presently, professional courtesy has been extended in the following way:

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<th>Answer Choices</th>
<th>Responses</th>
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<tbody>
<tr>
<td>I am consistently addressed as doctor in the presence of staff and clients</td>
<td>73.30%</td>
</tr>
<tr>
<td>I am addressed as doctor inconsistently</td>
<td>21.47%</td>
</tr>
<tr>
<td>I am rarely addressed as doctor by anyone on staff</td>
<td>2.24%</td>
</tr>
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Another critical area of the workplace environment is performance feedback. The survey shows that again there is serious room for improvement. Respect

The Work Environment

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
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<tbody>
<tr>
<td>Is safe, professional, and courteous</td>
<td>37.70%</td>
</tr>
<tr>
<td>Isn’t as positive as I would like but it is okay</td>
<td>37.70%</td>
</tr>
<tr>
<td>Is more stressful than it needs to be due to management inaction</td>
<td>21.99%</td>
</tr>
<tr>
<td>Is unpleasant and stressful</td>
<td>2.62%</td>
</tr>
</tbody>
</table>

The failure of management to create a positive, productive work environment leads associates to consider leaving their position for this reason alone.

I Think About Leaving My Job Because of Work Environment Issues

<table>
<thead>
<tr>
<th>Answer Choices</th>
<th>Responses</th>
</tr>
</thead>
<tbody>
<tr>
<td>Never</td>
<td>34.03%</td>
</tr>
<tr>
<td>Sometimes</td>
<td>35.60%</td>
</tr>
<tr>
<td>Often</td>
<td>16.75%</td>
</tr>
<tr>
<td>Daily</td>
<td>13.61%</td>
</tr>
</tbody>
</table>
4. Case Study
A four-doctor mixed animal practice, located in Texas, with a single practice owner, a practice manager/lead receptionist, two receptionists, seven full-time technicians and two other staff members. Affluent clientele willing to pay for quality medicine. No procedures in place to manage human resources (HR) issues.

An overview of the HR problems include the following:

- Receptionists not answering the phones, forwarding them to the machine whenever they feel like it.
- Rude phone manners and a refusal to accept any training to improve their phone techniques.
- Staff creating their own schedules and deciding when they will or will not work.
- Employees are on the clock while not actually engaged in any meaningful work.
- There are no job descriptions with essential functions.
- There are no reviews or disciplinary procedures in place.

The current situation has cost the practice money in a wide variety of ways. Appointments not booked because the front office did not answer the phones. Clients leave the practice due to rudeness from the front office. Employees have been let go without proper documentation leading to unemployment claims against the practice. Fears of future unemployment claims have created an environment where unfit employees are allowed to keep their jobs increasing payroll expenses while decreasing productivity of the entire staff. Associate veterinarians find themselves unable to maximize their productivity due to inadequate/incapable staffing. This creates a high level of job dissatisfaction among associates further lowering their productivity. The practice manager has no training in HR issues and no support from the owner in addressing these issues.

While the practice is able to practice high-quality medicine, the bottom line is deeply affected by money lost from the toxic work environment. For example, the average amount of money spent on a routine equine veterinary visit in the South is $220. \(^1\) If the front desk neglects to answer the phone for just one of these appointments per week it will cost the practice $11,440 in lost revenue per year.

Proposed solutions include HR training for the practice manager:

- Job descriptions with essential functions created for each position.
- Review forms for each position.
- Disciplinary actions clearly stated in the policy manual.
- Proper documentation of disciplinary actions to prevent unemployment claims and enable the removal of nonperforming staff.

Most of these solutions do not cost the practice anything in hard currency, only in time and implementation. This practice would see a spike in profitability undertaking these solutions. At present, management finds it easier to do nothing and lose profitability than to take action a gain profit.

5. Discussion
The workplace environment is a seriously overlooked component of practice profitability. Neglecting these issues increase the costs of running a practice and increases the level of stress felt by the employees of the practice.

A special report in *JAVMA* sought to identify workplace stressors in veterinary medicine. Fifteen categories of practice-related stressors were listed and many included subcategories. Three of the fifteen categories were work environment related. These are listed below:

<table>
<thead>
<tr>
<th>Work Environment Category</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coworker or interpersonal issues</td>
<td>12.7%</td>
</tr>
<tr>
<td>Lack of support</td>
<td>2.4%</td>
</tr>
<tr>
<td>Work Environment</td>
<td>1.6%</td>
</tr>
<tr>
<td>Abusive or bullying coworkers</td>
<td>1.4%</td>
</tr>
<tr>
<td>Management issues</td>
<td>8.3%</td>
</tr>
<tr>
<td>Lack of support or guidance</td>
<td>2.5%</td>
</tr>
<tr>
<td>Abusive or bullying management</td>
<td>1.7%</td>
</tr>
<tr>
<td>Training or staffing</td>
<td>5.1%</td>
</tr>
<tr>
<td>Low skill staff or lack of training</td>
<td>1.8% (^5)</td>
</tr>
</tbody>
</table>

This comes to a total of 37.50% of the stressors in veterinary medicine arising from poor or nonexistent management. Many of the stressors in veterinary medicine are beyond the control of management. Client behavior such as unrealistic expectations of treatment, the overall economy, and government policies are stressors that cannot be addressed by management or easily changed. It is therefore imperative for management to address and change the things they can control. At present, the survey indicates much room for improvement in this area. Less than half of the veterinarians surveyed indicated that management took action on workplace issues.

Failure to take action may indicate a lack of management training on how and what kind of action is appropriate and a lack of knowledge on how to execute the action. Inaction can also be seen as a failure of leadership. While it is easier to “hope the
Mistakes by employees can be a major reason for management to react in an uncivil manner. This is not the only reason for this type of behavior in the workplace. Studies on the subject came up with a wide variety of reasons. More than half claimed they were overloaded and more than 40% said they had “no time to be nice.” Twenty-five percent said they were rude because their leaders were disrespectful. Another quarter said that their companies lacked guidelines or training about how to treat people.

The costs of incivility are immense. A look at what incivility does to the productivity of workers is listed below:

- 48% intentionally decreased work effort.
- 47% intentionally decreased their time spent at work.
- 38% intentionally decreased the quality of their work.
- 80% lost work time worrying about the incident.
- 63% lost work time avoiding the offender.
- 66% said that their performance declined.
- 78% said that their commitment to the organization declined.
- 12% said that they left their job because of the uncivil treatment.
- 25% admitted to taking their frustration out on customers.

In a veterinary setting the costs of rude behavior can be even higher: it can lead to medical errors and
cause patient death. People on the receiving end of rude behavior have their thoughts hijacked by the incident. The mind tends to dwell on the insult, not on the task at hand. This can have disastrous results in medicine. In a study of 4500 medical doctors and nurses, 71% tied disruptive behavior (defined as “abusive personal conduct,” including condescending, insulting, or rude behavior) to medical errors they knew of and 27 percent tied disruptive behavior to the deaths of their patients. The results from the survey show that disruptive behaviors lead to potentially preventable adverse events, errors, compromises in safety and quality, and patient mortality. Strategies to address disruptive behaviors should prevent disruptive events from occurring, deal with events in real time to prevent staff or patient harm, and initiate post-event review, actions, and followup.6

A veterinary hospital must create a culture of civility to create a work environment conducive to high-producing employees and outstanding care. Management, doctors, practice managers, and team leaders are all accountable for the level of civility in their work environment. Failure to set boundaries on workplace behaviors creates fertile ground in which incivility can grow.

Part of maintaining civility in the workplace comes from appropriate training. Employees should be trained on how to address doctors, managers, and coworkers. As mentioned earlier, boundaries should be set as to what behavior is and is not acceptable. How coworkers treat each other should be part of the mission statement or otherwise outlined in the policy manual. Look to the mission statements of successful companies for ideas on how to verbalize civility. Southwest Airlines Mission statement contains the following: “Above all, employees will be provided the same concern, respect and caring attitude within the organization that they are expected to share externally with every customer.” Dignity Health's list of values includes respect for the inherent worth of each person, collaboration, justice (including advocating for social change and act in ways that promote respect for all persons and demonstrate compassion for those who are powerless), and stewardship (cultivation of the resources entrusted to us to promote healing and wholeness). Starbucks company values include, “Creating a culture of warmth and belonging, where everyone is welcome” and “Being present, connecting with transparency, dignity and respect.”

Another facet of maintaining civility in a veterinary hospital is the disruptive client. Some clients are verbally abusive to staff, others are harassers. In either case, it is up to management to quell this behavior either by discussions with the client or by firing the client. In general, these scenarios are relatively rare, but they must be addressed for the staff to feel safe at work.

Management must avoid the creation of a hostile work environment and that includes addressing sexual harassment. A clear definition of sexual harassment is necessary to understand what is and is not acceptable. Sexual harassment includes unwelcome sexual advances, requests for sexual favors, and other verbal or physical conduct of a sexual nature. There are two types of sexual harassment recognized by federal law: quid pro quo and hostile work environment. Quid pro quo refers to situations where employment decisions such as hiring, firing, or promotions are contingent upon the employee providing sexual favors. Examples of quid pro quo sexual harassment are when a supervisor threatens to fire an employee who does not submit to sexual advances or where a supervisor promises to promote an employee in exchange for sexual favors.

Hostile work environment sexual harassment refers to situations where the employee’s work environment is made intimidating, hostile, or offensive due to the unwelcome sexual conduct and the conduct unreasonably interferes with the employee’s work performance. This could take the form of unwanted sexual advances by a fellow employee, but it need not involve sexual advances at all. Examples of hostile work environment sexual harassment include making offensive sexual comments or jokes, discussions about sex, and the display of sexually oriented materials.7

Sexual harassment occurs in veterinary hospitals as it does in any other workplace. It is perpetrated by doctors, clients and coworkers. Part of effective employee training is to educate the employee what to do and who to report to if harassment is occurring. It is then up to management to investigate and act appropriately. Failure to do so not only creates a work environment where employees feel unsafe, it leaves the practice open to legal action.

To create a safe work environment, violence and the potential for violence in the workplace must be addressed. Workplace violence occurs in the veterinary workplace as it does in any segment of business. According to the FBI, the perpetrators of workplace violence can be broken into four types (Table 1).

The first strategy employed to combat workplace violence should be prevention. This falls under the heading of “know your employee.” When employee behavior changes it should be reviewed to determine if it is a behavior of concern. Behaviors of concern can help workers recognize potential problems with fellow employees. If a co-worker begins acting differently, determining the frequency, duration, and intensity of the new, and possibly troubling, behavior can prove helpful.

Specific behaviors of concern that should increase vigilance for coworkers and supervisors include sadness, depression, threats, menacing or erratic behavior, aggressive outbursts, references to weaponry, verbal abuse, inability to handle criticism, hypersensitivity to perceived slights, and offensive commentary or jokes referring to violence. These behaviors—when observed in clusters and coupled with diminished work performance (as manifested...
by increased tardiness or absences, poor coworker relations, and decreased productivity)—may suggest a heightened violence potential. It must be pointed out, however, that no single behavior is more suggestive of violence than another. All actions have to be judged in the proper context and in totality to determine the potential for violence.

Not surprisingly, relationship problems (e.g., emotional/psychological or physical abuse, separation, or divorce) can carry over from home to the work setting. Certain signs that may help determine if a coworker is experiencing such difficulties include disruptive phone calls and emails, anxiety, poor concentration, unexplained bruises or injuries, frequent absences and tardiness, use of unplanned personal time, and disruptive visits from current or former partners. Care must be taken when dealing with what can be highly charged situations. Companies may lack the expertise to handle these on their own and may have to consult with experienced professionals. Finally, all incidents are different and must be viewed on their own individual merits. Experience has shown that no one-size-fits-all strategy exists.8

Staff should be made aware if a client exhibits these behaviors of concern in response to a poor outcome. Any threat of violence made by a client should be reported to local law enforcement. Recognition of the potential for workplace violence and what to do in the case of workplace violence should be a part of staff training. Local law enforcement is generally available to conduct seminars on the subject of workplace violence and this resource should be utilized. All members of staff will feel safer and more confident if they are educated on workplace violence.

Only 35.48% of surveyed veterinarians rated their workplace as safe, professional, and courteous. This indicates much more needs to be done by practice owners and management to improve their workplace. Practice owners should consider professional management of their practice if they are not interested in the management aspect of their business. As it has been outlined here, failure to manage is too costly to ignore. The acquisition of a practice manager or hospital administrator will free up the owner/veterinarian to focus on the practice of medicine and limit their administrative time to major issues and then delegate the resolution of them to the practice manager. This improves practice profitability two ways, the owner/veterinarian has more time to practice and the workplace environment issues are addressed and resolved.

To determine to what extent the workplace environment affects job satisfaction the survey asked how often participants considered leaving their job due to work environment issues. The responses indicate only one third of veterinarians never thought about leaving their jobs because of workplace issues. Fully two thirds of the respondents gave some thought about leaving their positions and half of those thought about it often or daily. Replacing departing associates is time consuming and expensive.

6. Conclusion
The costs to a veterinary practice from failure to manage the work environment are steep. Costs can arise from decreased employee productivity, employee turnover, unemployment claims, lost clients, medical mistakes, and lawsuits.

Staff must be properly trained, evaluated, and motivated to yield productive, profitable performance. Top-tier performance can only occur when the work environment is safe and civil. Creating and supporting this type of work environment will increase practice profitability through outstanding workplace performance and dedication. Veterinarians must consider the workplace environment as well as the quality of medicine practiced when considering a position. Practice owners and/or management must improve and be willing to make the changes necessary for creating a positive workplace environment. These steps include managing the behavior of support staff and clients, setting the standard of behavior for associates veterinarians as well. A system of regular evaluation and feedback for all employees needs to be in place. Practices should have a process for employees to bring issues to management. This process should include reporting back to the person who made the complaint on what if any action was taken and the reasons for the course of action. Failure to follow these steps increases the costs of running a practice and decreases profits and decreases the workplace satisfaction of all employees and the practice owner.

Acknowledgments

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

Table 1. Classification of Workplace Violence Acts
Type of Act | Description of Act
--- | ---
Type I | Offender has no relationship with the victim or workplace establishment. In these incidents, the motive most often is robbery or another type of crime.
Type II | Offender currently receives services from the workplace, often as a customer, client, patient, student, or other type of consumer.
Type III | Offender is either a current or former employee who is acting out toward coworkers, managers or supervisors.
Type IV | Offender is not employed at the workplace, but has a personal relationship with an employee. Often these incidents are due to domestic disagreements between an employee and the offender.

This table was reprinted from FBI Law Enforcement Bulleton, Jan 2011.
Conflict of Interest
The Author has no conflicts of interest.

References
Use of an Employee Engagement Survey to Improve Business Culture, Productivity, Profitability, and Client Loyalty

Mike Pownall, DVM, MBA

Disengaged employees are a cause of decreased morale, productivity, profitability, and increased employee turnover, burnout, and client complaints. Use of a standardized employee engagement survey can give a business key insight into employee engagement that can be the basis for management changes that can lead to increased practice productivity, profitability, and client loyalty with happier and more motivated employees. Author’s address: McKee-Pownall Equine Services, PO Box 459, Rockwood, ON N0B 2K0, Canada; e-mail: mike@mpequine.com. © 2018 AAEP.

1. Introduction
As a veterinary business owner or manager there is nothing more frustrating than having a veterinarian or support staff member that just doesn’t seem to care. They started their career with you full of enthusiasm and motivation working as part of the team and then over time their energy seems to drain, they take more days off, they aren’t as polite or respectful to co-workers and customers. Even worse is when their attitude starts to spread and infects other team members. When you ask your staff why they seemed disengaged they give generic responses that don’t seem to give you any information that you can use to improve their situation. Ultimately, this loss of company-wide employee engagement leads to decreased productivity, reduced revenue, increased employee burnout and higher employee turnover, and more client complaints.

A couple of years ago this was what we faced in our practice. We try to create a culture of collaboration and support between team members, but we had noticed that some of our vets were getting close to burnout in the busy season, and we had a revolving door of technicians and receptionists, which led to more frustrations for our vets. It was a vicious cycle that we had to stop but didn’t know how. Then one day I read an academic paper in the MIT Sloan Management Review about employee engagement surveys and thought, “we need to try this.” Maybe this can help us identify how great staff are turning sour over time.”

Ideally what we want are employees who are engaged at work. Employee engagement is the emotional commitment that an employee has for the company and its goals. Engaged employees care about their own work and the work of the company—they are more willing to go the extra mile for clients and each other. Studies have shown that companies with highly engaged employees are more productive. A recent meta-analysis from the Gallup company found that companies in the top 25th percentile of employee engagement had the following increases when compared to the bottom 25th
percentile of those on the study; 10% in customer loyalty, 21% in profitability, and 20% in productivity.3

2. Solution
The authors of the MIT study found that there are five “dimensions” of employee engagement: employee satisfaction, identification, commitment, loyalty, and performance.

Employee satisfaction is described as the positive response employees have to the overall circumstances of their job. This includes their relationships with management and co-workers and their overall compensation. Satisfied employees are committed to their work and have less absenteeism. This results in a better quality of the work they perform. These employees also have a better connection to the values and goals of the company and feel that they are part of the organization.

Employees who identify with their company feel that they are part of any successes or failures in the company. They take any compliment to the company personally.

Employees who have more commitment to the company will work above and beyond their job description. Highly committed employees are the ones that will stay late to help or will take on another task beyond the scope of their position. These employees also perform better and are less likely to leave an organization.

Loyalty to a company from its employees is shown as a positive attitude about the company. Loyal employees will do more for the company and this leads to increased client satisfaction.

Employee performance is related to the quality of the services that the company produces and customer interaction.

In order to measure employee engagement, the authors of the paper created an employee engagement scorecard that measures the five components of employee engagement. Individual questions are scored on a scale of 1 to 5, with 5 indicating that the respondent strongly agrees with the statement with 1 stating that they strongly disagree. Each of the five components has several questions that are aggregated to give an overall score for that section, which is converted to a percentage. The overall engagement score is the addition of each of the 5 sections.

Based upon the results of the score card in 75 companies in Asia, Europe, and North America they found that the overall scores could be placed into one of four groups.

• 20–39%—low engagement.
• 40–59%—More engagement, but that attention was required on some of the components.
• 60–79%—These companies had a higher level of employee engagement that allowed them to operate well; there was still room for improvement.
• 80–100%—These companies followed best practices for employee engagement.

With the framework of this scorecard we created our own survey that featured 5 categories with a total of 34 questions that were sent to staff via an email survey. Responses were anonymous and separated into 3 categories: veterinarians, receptionists and office staff, and veterinary technicians. We allowed an area for comment under each question. Examples of the categories and questions are as follows.

Career Development
• I am satisfied with my opportunities for growth within the practice.
• I am satisfied with the internal (in-house) job-related training the practice offers.
• I am satisfied with the amount of time and money the practice invests in my CE (training courses offered by outside sources—courses, workshops, etc.).

Work Engagement
• I am inspired to meet my goals at work.
• I am proud to tell people where I work.
• I have a sense of ownership in the practice.

Compensation and Benefits
• I feel that I am compensated appropriately overall (including wage/salary and bonus).
• I am compensated fairly relative to similar/the same positions in similar businesses in my area.
• I am confident that the method used to determine my wage or salary increases on a yearly basis is fair.

Relationship Management
• Communication between management and employees is excellent at the practice.
• I am involved in the decisions that affect my work at the practice.
• Management at the practice recognizes strong job performance.

Work Environment
• The work at this veterinary practice positively impacts clients’ lives.
• I am happy with the overall culture of the practice.
• I understand how our Core Values relate to expectations around my behavior at work, and my work itself.

3. Results
We have performed employee engagement surveys in the springs of 2016 and 2017 at our veterinary practice, ZZZ Equine Services.
Since the introduction of our first employee engagement survey we have been able to offer the same survey to 14 other equine practices in North America, Germany, and the Netherlands.

### Table 1. ZZZ Equine Services 2016

<table>
<thead>
<tr>
<th></th>
<th>All EEs</th>
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<th>Admin</th>
<th>Techs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total career development</td>
<td>4.0</td>
<td>3.9</td>
<td>4.3</td>
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<tr>
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<td>77%</td>
<td>73%</td>
<td>81%</td>
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### Table 2. ZZZ Equine Services 2017

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### Table 3. Combined NA and EU

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### Table 4. North America

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### Table 5. Germany and The Netherlands

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<td>Overall total</td>
<td>3.5</td>
<td>3.6</td>
<td>3.5</td>
</tr>
<tr>
<td>Percentage total</td>
<td>71%</td>
<td>72%</td>
<td>70%</td>
</tr>
</tbody>
</table>

### 4. Discussion

Our initial survey in 2016 showed that our company of 10 veterinarians and 20 support staff had an overall score of 77%, which indicates a high level of employee engagement with room for improvement. A key finding for us was that our veterinarians were less engaged overall than our support staff (73% versus 81%). The key areas of concern were found in the components of Work Engagement, Compensation and Benefits, and Relationship Management. Specific scores and comments told us that the main areas of concern were that our vets were tired and potentially suffering from “burnout.” They were working 5 days a week, but the days were very long with appointments, client communication, and medical recordkeeping typical to equine veterinary practice. What we also identified was that the veterinarians did not feel that they were being compensated enough compared with colleagues working with other species. While compensation was a concern for support staff it was especially important to our veterinarians. In addition, our management team was not effectively communicating with our veterinarians. In my role as president I didn’t seem involved with the day-to-day activities of the practice and it reflected on everyone else.

The comments were especially revealing. The anonymity of the survey gave everyone carte blanche to share what they wouldn’t tell us in person. It gave specific examples of what we needed to do to improve.

As a result of the survey, we changed the schedules of the veterinarians to give them a 4-day work week without changing their compensation. In essence they were able to work 1 less day while still being paid the same. I also focused more on being more engaged myself in the daily activities of the practice and the activities of our veterinarians.

In the spring of 2017 we repeated the survey and the results justified our actions the previous year. Our overall score improved by 3% to just shy of 80%. The big improvement came from the vet’s responses; what we did the year before was appreciated. Our vets were much more engaged. Not only did our veterinarians seem happier at work, but despite the 20% decrease in veterinary capacity our revenue...
grew 13% from January 1 to June 30, 2017, compared with the same period the year before when the veterinarians were working 5 days a week. There was also a noticeable change in mood around the clinic. Previously, by the time the spring vaccine and horse show preparations were completed our vets were very tired and subdued. In 2017 we found our veterinarians were in great spirits and were often found laughing in the shared vet office compared to the same period in previous years. Not only was our business more profitable, but the overall mood and culture had improved. Everyone was working seamlessly together. Being at work was much more enjoyable.

Not all was as good as it could be in 2017 though. We found that we needed to do something for our support staff. Their main concern was their lack of appropriate compensation, so we adjusted and updated our wage ranges, giving significant raises to support staff across the board. We were confident to do this since we knew that our efforts with the veterinarians the year before were so appreciated.

Since the introduction of our first employee engagement survey we have been able to offer the same survey to 14 other equine practices in Germany, Netherlands, New Zealand, and North America.

The overall employee engagement score for these practices was 74%. There were three areas of concern; career development for technicians, compensation, and relationship management for all employees. We then separated the nine North American practices from the five practices in the Netherlands and Germany and compared their scores. The overall scores for the North American cohort was 76% versus 71% for the Dutch and German veterinary practices. The main differences between the two groups was in career development for support staff and technicians (68% versus 61%) and compensation for veterinarians and support staff. Veterinarians in North America had a compensation and benefits score of 74% compared with a score of 61% for the European sample. Similarly, North American support staff scored their compensation and benefits engagement at 71% versus 59% for their counterparts in The Netherlands and Germany. The comparison between the North American businesses and those in Europe were in line with employee engagement scores in other industries; employees in North America are more engaged than those in Europe.4

The sample size for our global employee engagement survey is not adequate to make declarations about differences between countries with any certainty. Rather, it gives us the basis for a more comprehensive study. We are currently working with a veterinary school in Europe to conduct a statistically significant study comparing employee engagement scores between North America, Germany, The Netherlands, and the United Kingdom. Our goal is to identify baseline scores between the regions as well as give us insight into different practice types. For example, how do ambulatory practices compare to hospitals, or what is the difference between a total staff of 10 or less versus larger practices.

The effect that employee engagement has on business productivity, profitability, morale, and culture are significant. Various studies have found that disengaged employees cost a company $3,400 per $10,000 in salary annually. The inevitable employee turnover from disengaged employees cost companies about 48% to 61% of the lost employee’s salary.5

There are several things a company can do to improve employee engagement. Job orientation, ongoing training, opportunities for career advancement, acknowledgment of good performance, and adequate compensation are key elements in a culture of employee engagement.

Doing an employee engagement survey can be a powerful tool for Human Resource (HR) management. It provides key insights to measure the success or failure of your HR strategy that would otherwise not be available. It also shows your employees that you value their opinion and gives you a basis to implement positive change in your business.

Working in an equine vet practice is a tough job for various reasons. According to the 2016 American Association of Equine Practitioners—AVMA Economic Survey, 50% of new equine practitioners leave the American Association of Equine Practitioners as members.6 Employee engagement is one piece of the puzzle to help the profession reduce this turnover of new practitioners. Finding out to what degree disengaged employees is part of this problem and then providing ways to improve employee engagement is valuable to keeping veterinarians in the profession. Other benefits include improved patient and client outcomes, better practice culture and increased productivity and profitability.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References


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How to Create an Employee Manual for Your Practice

Amy L. Grice, VMD, MBA

1. Introduction
An employee manual memorializes a veterinary practice’s policies and procedures, as well as communicates expectations to employees. It also helps protect the business in the event of a dispute with a disgruntled employee. Employee handbooks are a vital communication tool for small-business owners. They are a helpful tool for introducing new employees to your policies about everything from vacation to social media, and are also an important piece of your risk-mitigation plan.

2. What Is an Employee Manual?
An employee manual describes all of a business’s policies and procedures, and sets expectations for employees. In some states, the employee manual may be viewed as an employment contract, so by including precise language and effective disclaimers, it can effectively shield your practice in the event of future conflict and provide legal protection. A good handbook balances being clear and concise with being legal and thorough. The best objective of an employee manual is to describe all your compliance and legal obligations as an employer.

3. Why Should I Have an Employee Manual?
The most important reason for writing a handbook is that the process itself will force you to think through and create policies that you may have never considered. Because as a practice owner you spend most of your effort working as a veterinarian to produce revenue, managing your practice often is reactive, and only when a situation requires it. Once you create an employee manual, you can more easily manage employees, as well as address potentially disruptive issues before they occur, allowing your business to run more smoothly.

   By providing a document that clearly spells out your expectations for employees, you can also often avoid legal trouble. Written policies allow your team to understand how your practice manages different situations, what the boundaries are, and what the consequences are when the boundaries are breached. An employee handbook also provides an opportunity to showcase how the practice values its staff members. Using positive language to describe the business can help create employee pride and motivation.

4. What Are the Essential Sections of a Well-Written Employee Handbook?

   Introduction and Welcome
   In this section, create a statement of the purpose of the handbook—how it’s meant to establish expectations, inform employees of your policies and pro-
policies, and provide an overview of the work environment. You also have an opportunity in this opening portion to welcome new employees and share the history of your practice, so they will understand your business’s foundation. Include your practice’s mission statement, vision statement, and practice values, creating transparency of the company’s goals, philosophy, and core principles. However, avoid describing the company as “like a family,” because that could imply a promise of indefinite employment.

You must include statements regarding the non-contractual nature of the handbook. Be sure to state that employment at your practice is at will. An at-will employment relationship can be terminated at any time, with or without reason or notice by either the employer or the employee. Nothing in your handbook should be construed to alter that at-will relationship.

**Workplace Compliance**

This section includes statements about how your practice complies with equal employment opportunity and prohibits unlawful discrimination and harassment. Discrimination is strictly prohibited by a variety of federal, state, and local laws, including Title VII of the Civil Rights Act 1964, the Age Discrimination Act of 1975, and the Americans with Disabilities Act of 1990. Your policy is intended to comply with the prohibitions stated in these antidiscrimination laws. The US Equal Opportunity Employment Commission enforces laws that prohibit workplace discrimination. For example, the Americans with Disabilities Act requires employers to provide (among other things) reasonable accommodations to qualified individuals with disabilities unless to do so would cause an undue hardship to the company.

You must state that your practice won’t tolerate discrimination or harassment based on race, color, religion, creed, sex, national origin, age, disability, marital status, veteran status, or any other status protected by applicable law. Your policy should describe that it applies to all terms, conditions, and privileges of employment, including recruitment, hiring, placement, compensation, promotion, discipline, and termination. You should also be sure to research and abide by state and/or local laws, which may differ from the federal discrimination laws by being more stringent. In addition, describe that your company is in full compliance with immigration laws.

**Company Policies and Procedures**

This section is utilized for stating your policies for use of practice property, confidentiality, privacy, drug and alcohol use, and social media. You should describe the disciplinary action that may result if any of these policies are violated. Your policy should be explicit in describing what employees can and cannot do with equipment, vehicles, telephones, computers, and software. It is recommended that you include a policy that describes a drug/alcohol-free environment. You should also state that employees are free to bring forward any concerns or problems they might have and explain who they should talk to if it isn’t you they should seek out. Inform your employees in this section about your practice’s policies on confidentiality, conflicts of interest, dress code, outside employment, continuing education allowances, and expense reimbursement.

**Employment Classification**

The Fair Labor Standards Act (FLSA) defines how employees qualify for overtime exempt status. It is important to state clearly how employment classification and overtime rules are followed at your practice in accordance with state and local laws and the FLSA. This section is where you should define part-time, full-time, or temporary status for employees, clearly outline the requirements for each classification at your practice, and explain how benefits are apportioned.

Because exempt employees are not paid overtime, there are rules which are codified in the FLSA regulations about who can qualify as exempt. These qualifications include meeting a certain salary threshold and performing certain types of job duties. Misclassification of employees as exempt when they do not qualify can result in large fines. If you have any questions about whether an employee qualifies to be paid an exempt salary, consult the Department of Labor Web site or an attorney for more information.

**Attendance Policies**

This section should deliver clear details on your practice’s expectations and requirements for attendance, work hours, and schedule. Policies on punctuality and absenteeism belong here. If the practice has multiple locations, information about differing hours of operation, and how that affects attendance is shared here. If you have a system for tracking hours worked, whether a timeclock or a timecard, your policy should be described. A policy that provides details on how employees can properly schedule time off must be clarified. In addition, disciplinary action for unauthorized or chronic absenteeism should be described. Laws regarding break and meal periods differ by state, so it is necessary to research these and then provide required meal and break times.

**Leave Policies**

In this section, you should detail practice policies, including eligibility requirements, for all time away from work. This includes sick and personal leave, vacations, disability, and anything involving time off work for employees, especially those absences required to be allowed by law. Generally, although most states do not require vacation benefits for employees, most employers offer them. If you have a
policy for how vacation time is accrued, it should be included in this section. States are also increasingly requiring employers to provide a minimum number of paid sick leave days to employees, so this is an area to research so that your paid time off policies follow the law. Your practice’s policies on family medical leave, jury duty, military leave, and time off for court cases and voting must comply with all applicable laws and should be described in detail in this section. In addition, explain your policies for vacations, holidays, bereavement, and sick leave. Consult with an employment attorney regarding your legal obligations if you have any questions.

The Family and Medical Leave Act (FMLA) applies if your company has 50 or more employees, but many practices with less than 50 employees voluntarily offer unpaid leave in accordance with the FMLA. If you choose to do this, your handbook may include an FMLA section, which can be researched on the Department of Labor Web site. Regardless, it is recommended that you establish a leave of absence policy to consider employees’ requests for unpaid leaves of absence, because they are not uncommon.

Work Performance
In this section, detail expectations about mutual respect, common courtesy, and consequences for insubordination. You should describe how employee performance will be assessed and that you expect satisfactory performance of job duties from employees. By following a performance review policy at your practice, you can often avoid problems that result after “poor performance” terminations. You will want to share how often employees may expect a review. Although you may state that your practice has a review policy, it is not necessary to include the whole policy in the handbook, unless it is brief.

Discipline Policy
This section clearly communicates expectations and consequences, and describes what constitutes grounds for disciplinary action. It is important to have a methodology for hearing both sides of the story, however. You will want to describe the progression of actions that you may take, including verbal warnings, written warnings for continued problems, probation, and termination. It is recommended that you describe how employees are given a chance to communicate grievances. Remember that problems can have levels of severity, so be careful that you leave yourself latitude in your responses.

You must be careful not to describe a rigidly progressive discipline system, because placing that policy in a handbook can be binding and defeat the purpose of an at-will employment relationship. If you state to your employees that you follow a fixed method for discipline in every instance, you could become liable for not adhering to your own policies in every situation. Do not make statements about discipline policy steps that you might not always take. Utilize the words “may include” instead.

Employee Health and Safety
In this section you may include information about health insurance, a company retirement plan, workers’ compensation, disability coverage, and discounted veterinary services, if applicable. Because formal plan documents for most of these programs are held separately, and contain detailed information about benefits, you don’t need to document them thoroughly here, but instead refer to the plan documents, and include a basic description of the benefits offered, the eligibility requirements, and contact information. For in-house benefits such as discounts for personal pets, you will want to clearly delineate your practice’s policy.

It is very important to include a disclaimer that in the event of any inconsistencies between your handbook or any other oral or written description of benefits and a formal plan document, the formal plan document will be official. Even with a disclaimer, you may want to schedule an annual review of your employee manual to make sure your benefit plan description in the handbook aligns with your company’s most current formal plan documents.

Termination Policies
In this section, acknowledge that situations may arise that require a voluntary termination of employment. Outline your expectations that an employee provides at least 2 weeks’ advance written notice of their departure and that this request does not alter an employee’s at-will relationship with the practice. You will want to detail the events that occur upon voluntary or involuntary termination, including any compensation still due, unused paid time off, and return of practice property such as keys, cell phones, computers or vehicles. If an employee is a veterinarian, your practice may have policies that require a departing associate to reimburse you for the remaining term of their PLIT insurance or for continuing education expenses in excess of the annual budget.

You should also include language that explains that all rights and privileges of employment with the company terminate upon the date of separation, that terminated employees must return all company property assigned to them, and that failure to do
so may result in the withholding of their final paycheck.

Acknowledgment of Receipt
You will need to include a separate acknowledgment page to be signed by the employee, stating they have received, read, and understood the handbook. Having the signed acknowledgment of receipt prevents an employee from claiming to be unaware of the policies of the practice. It is difficult to enforce rules an employee can claim they didn’t read and/or understand, so the signed acknowledgment page should be retained in the employee’s personnel file.

5. Summary
An employee handbook can diminish the stress and risks of practice ownership by spelling out policies and expectations for employees. If you are unsure about any part of your employee handbook as you create it, research the law, contact the proper state or federal agency, and/or consult an attorney. All employee handbooks should be reviewed by an attorney in your state to ensure compliance with federal and state laws and regulations.

6. Resources


Acknowledgments

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

Conflict of Interest
The Author is a self-employed business consultant.

References


We Survived... Three Consecutive Maternity Leaves

Miranda Gosselin, DVM

This paper will discuss lessons learned when a five-doctor equine practice decides to invest in its employees through communication, creative on-call scheduling, paid maternity leave, and nontraditional scheduling. Author's address: 3967 Route 44, Millbrook, NY 12545; e-mail: mepgosselin@gmail.com. © 2018 AAEP.

1. Introduction

Historically speaking, our profession has not been progressive in our approach to human resource management of employees during and after pregnancy. While the majority of practice owners have been avoiding this issue, even going so far as to stigmatize pregnancy, the demographics of equine practitioners have continued to change.¹ As of 2017, more than 80% of veterinary students were women, a rising trend that has been occurring since the early 1970s.² Furthermore, the AVMA observed that female equine practitioners outnumber their male counterparts 53% to 47%, respectively as of 2017.³ Of the total number of veterinary school graduates from 2010 to 2014, only 1.9% pursued equine practice, which is also a negative trend from historic averages of around 5%.⁴ These trends are logical considering the current starting salary and rising debt load of our new graduates. It’s alarming but perhaps not surprising that the attrition rate for young equine veterinarians is the highest of all the subsets of veterinary practice; where in 2007, 37.5% of young veterinarians within 4 years of graduating did not renew their American Association of Equine Practitioners membership.⁵ The remaining small population of new graduates that are interested in equine practice are struggling to afford this career path and many choose to leave due to lifestyle. As parental policies contribute to lifestyle, it’s time for practice owners to adopt a proactive approach to parental leave and nontraditional scheduling. The following is a description of one practice’s approach.

2. Solution

“Millbrook” Equine Veterinary Clinic is a five-doctor ambulatory practice located in New York’s Hudson Valley. All five veterinarians are women and four of the five either have children or are of child-bearing age. In the summer of 2016 it became clear that three of the five veterinarians were going to have a baby within a 7-month span. The ownership was obviously excited, but suffered the usual anxiety of how to support these women during their pregnancy and postpartum period and maintain the practice. Luckily, while the pregnancies overlapped, the postpartum period/requested maternity leave did not.

With the announcements of three pregnancies, the owners decided to hire an assistant. Prior to this period the business consisted only of three part-
nurs, two associates, and two office staff members. While one veterinarian was due in December, the other two were due in April and July. Therefore, if the owners wanted to maximize the pregnant veterinarians’ productivity during their busy season, they needed to hire a temporary associate. The assistant initially floated between all five veterinarians, but as soon as breeding season arrived, she was assigned to the theriogenologist exclusively. Beyond improving the efficiency and handling unruly horses, the assistant unloaded heavy equipment, shot radiographs (with supervision), performed flexion tests, and simply acted as a mother hen. Our pregnant veterinarians were more productive and safer with the assistant’s help.

Additionally, the owners actively communicated with the pregnant veterinarians: If she was not comfortable taking radiographs, they supported her decision and another veterinarian shot the X-rays. If she didn’t want to collect a stallion or manage a down horse, another veterinarian would help or would go. There were also times when the group would intervene and refuse a veterinarian from being on call or providing a service that was either unnecessary or unsafe.

As the pregnant veterinarians approached their due dates, each would automatically come off of the on-call schedule 30 days before her due date. The owners felt that it was neither beneficial for the practice or, many times, comfortable for the client to have a veterinarian out struggling to provide emergency services the day before she had a baby. If the veterinarian felt she needed to come off of the schedule before 8 months’ gestation, the team would discuss and adjust the calendar. Each pregnant veterinarian was given the freedom to decide how she could best contribute to the practice, thereafter. One associate sorted through and sold old equipment, another palpated mares right up until the week before her son was born. The owners recognized that each woman was different and each pregnancy unique. They trusted the team members to make the best decision for their body and their role within the practice.

During this time, the maternity policy included 4 weeks of paid leave that could be used in combination with paid vacation. A veterinarian could take a longer leave, but it was unpaid and she relied on income from state programs and/or third-party disability coverage. As of January 1, 2018, New York State enacted the Paid Family Leave Act. Under this law, employees in 2018 became eligible for 8 weeks of 50% of their average weekly compensation, capped at 50% of New York State’s Average Weekly Wage. According to the state’s Web site, the benefit is projected to increase annually to 67% of an employee’s average weekly wage over 12 weeks. This can be used in combination with paid maternity/paternity, state disability, and third-party disability.

The owners were committed to holding their employees’ positions until the veterinarians were ready to return to practice. With this commitment in mind, they hired a temporary associate for July through September. From November of 2016 through December of 2017, the practice was effectively down a person, which resulted in a rapid pace for everyone working. By the summer and early fall, everyone was exhausted and badly in need of some vacation time and reprieve from on-call. While the temporary associate was not profitable, she allowed the team a chance to recharge and protect their mental health. Additionally, she picked up the on-call weekends for an associate who was taking a longer, unpaid leave. Without the help from the temporary associate, they would have reinstated all of their returning veterinarians to the on-call schedule at 16 weeks. If not working full time, the returning veterinarians were compensated for their on-call time with a flat fee plus collected emergency fees for any of the work done.

In many ways, returning to work was more important than maternity leave. The owners learned to communicate closely with the returning veterinarian and allow her the flexibility she needed to set her own schedule. One veterinarian, a partner, came back to work part-time after a month of leave and returned to full-time work after 2 months. Another came back to work after 10 weeks and started a nontraditional schedule of 3 full days and 2 half days. Another was available for 2 to 3 scheduled days per month after 12 weeks but didn’t return to a regular part-time schedule until 6 months. She still working a part-time schedule and is free to determine when she wants to move to full-time.

Non-traditional scheduling is such an important part of supporting working parents with young families. It’s like putting together pieces of a puzzle: one veterinarian prefers a 4-day work week, while another wants to work the mornings and have the afternoons free. A third veterinarian needs the flexibility to work out 3 days per week, and a fourth doesn’t want to start work until after 9:00 am and wants Friday afternoon off. While some owners might bang their head against the wall forced to sort out this schedule, these owners have made it work. They expect the needs of every team member (partners and associates) to shift as their families change. They may have more veterinarians that want to get a later start because they want to get their children on the bus. They may have veterinarians that want to get an early start and not be available later so that they are free to pick up their kids and take them to activities. Anything is possible as long as they have the necessary coverage and everyone is transparent about their availability. The ownership is actively encouraging communication and approaching every challenge with the mindset of, “how can we make that work?” They’ve learned to trust their employees to do what needs to be done for the
practice. This results in company pride, loyalty, and job satisfaction.

Once a new parent has returned to practice, it is essential to support them as they find childcare. While there are a number of options available, the owners have found that veterinarians can't focus on work unless they are comfortable with their childcare provider. Childcare options include daycare centers, in-home daycare, and nannies. There are pros and cons to each option, but region, income, and other family factors, such as the spouse/other family member availability, play a significant role in the decision process. It seems obvious that models like those offered by the outdoor clothing and equipment company, Patagonia, where subsidized childcare is offered to employees, would improve the equine veterinary lifestyle and help to offset the often-debilitating expense of childcare. 7

3. Results

There is a misconception that 50% of working female veterinarians fail to return to the workforce following the birth of a child. While this statistic may be true of the general workforce, this has not been the case with equine veterinarians.1 It seems that practicing female equine veterinarians are dedicated to their profession, but there is room for human resource improvement. As a result of this partnership's willingness to be flexible and consider solutions outside of the box, all of their veterinarians returned to work in some capacity after the birth of their children. Beyond feeling good about the changes they made, there was an economic benefit as the business avoided the cost associated with employee turnover. The economic impact of employee turnover can range from 1.5 to 2 times an employee's annual salary.8 In the past year, despite paying three maternity leaves, employing a temporary associate, and switching to nontraditional scheduling, the practice was more profitable. Payroll expenses were down, mileage reimbursements decreased, and the ownership spent less on emergency fee compensation. Beyond the financial results, the team now communicates and supports each other better. When one veterinarian needs to work late, another helps out and picks up their child. The practice encourages discussion about kids and childcare, nanny shares, and breast milk/pumping. The practice is more like a family than it has ever been.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

2. WIA report: Tracking the progress of women in academia. At U.S. veterinary schools, women are 80 percent of students but 36 percent of tenured or tenure-track faculty. Available from: https://www.wiareport.com/2017/05/u-s-veterinary-schools-women-80-percent-students-36-percent-tenured-tenure-track-faculty/.
How to Create a Maternity Leave Policy for Your Practice

Amy L. Grice, VMD, MBA

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1. Introduction
Most veterinary practices will eventually have a pregnant employee in the workplace. Some of these pregnant employees are likely to be associates, because females are now dominating the ranks of new equine veterinarians. Figures of the Bureau of Labor Statistics indicate that fully 80% of all working women will become pregnant at some point in their working lives. In order to set expectations for all parties and insure that treatment of pregnant employees is lawful, practices should create maternity or parental leave policies.

2. Why Do I Need a Maternity Leave Policy for My Practice?
Historically, equine veterinary medicine was dominated by males, but this demographic is rapidly changing. Upon graduation from veterinary school, women are generally in their prime reproductive years. The 2016 AVMA AAEP Equine Economic Survey indicated that 69% of respondents either had children or planned to have children. Further, 74% of respondents reported that their employment agreement did not well address maternity leave. In addition, staff members in veterinary practices are primarily female, and many of them are of childbearing age. The occurrence of pregnancy in employees has not always been well managed by employers, and many practices have unwittingly behaved in a discriminatory fashion toward pregnant employees. Because laws are in place to protect pregnant employees, having a clear policy helps set expectations and insure compliance with state and federal regulations.

3. What Are the Laws Concerning Pregnancy and Maternity Leave?
Over the past few decades, the United States has passed major federal laws that provide legal protections to pregnant employees as well as employees who might become pregnant. These are Title VII of the 1964 Civil Rights Act, the Pregnancy Discrimination Act of 1978, the Americans with Disabilities Act (ADA) of 1990, and the Family and Medical Leave Act (FMLA) of 1993. Pregnant women are considered under the category of temporarily disabled.

The first of these laws was Title VII of the Civil Rights Act, which forbids employers with 15 or more workers on their payroll from refusing to hire, discharging, or otherwise discriminating against any person because of that person’s sex. However, the Supreme Court ruled in a mid-1970s case that discrimination based on pregnancy was not the same as...
discrimination based on sex. As a result, the Pregnancy Discrimination Act of 1978 was passed, which explicitly requires that all employers treat pregnant and nonpregnant employees equivalently, both in terms of benefits received and all other respects. This act requires employers to treat a pregnant employee the same as any other temporarily disabled worker, if she is unable to perform her work because of her pregnancy. Since the ADA was passed in 1990, accommodation of employees with disabilities has been a standard feature of antidiscrimination law for US employers having 15 or more employees. Some state disability laws are applicable to businesses with just a few employees.

In 1993, the FMLA was passed, which provided important federal protections for both men and women. The FMLA stipulates that employees may take as many as 12 weeks of unpaid leave annually for the birth or adoption of a child, care of a sick child, placement for foster care, or due to illness of themselves or an immediate family member. FMLA does not apply to businesses with fewer than 50 employees. Several states also have their own maternity leave laws and programs, so it is important to research your state regulations.

4. How Can My Practice Best Comply with These Laws?
Employers must provide the same benefits to all employees, whether or not they are pregnant. Employers must treat workers that are disabled equivalently. If an employer adjusts the workload for a worker who is not pregnant but who has some other disability or mitigating circumstance, they may not refuse to do so for a pregnant employee. Treatment of all disabilities must be materially equivalent. Employers may not forbid a pregnant employee from continuing to work if she wants to and is physically capable of doing the tasks associated with the position. If your practice allows unpaid leave for short-term disabilities, the same policy should be extended to your pregnant employees. Your practice should have a written policy about unpaid leave—under what circumstances it is granted, how long a leave is permitted, whether you will continue to pay for employee benefits during the period of leave, and what amount of lead time is required to request a leave. Many practices that are not subject to FMLA structure their policies to resemble the FMLA statutes.

5. Who Should Be Eligible for Maternity Leave?
When creating a maternity leave policy, it is important to consider the eligibility requirements that you may have in place for other disabilities. Can an employee with only 30 days on the job qualify for an unpaid leave if she breaks her leg while snowboarding? Be careful that you consider pregnancy-related and postpartum disability the same as all other temporarily disabling conditions. Under the FMLA, employees must have worked a total of 12 months, or 1250 hours in the prior 12 months, in order to qualify for the standard 12 weeks of unpaid leave. You may shorten this time period as you see fit, as long as you apply it evenhandedly. Another consideration is whether to offer parental leave in order to include fathers. And if you have husband and wife employees, will you allow them to share available leave time between them?

6. Should Leave Be Paid or Unpaid?
If you can afford it and have valuable employees that you want to retain, you may want to consider providing some type of pay in order to encourage your employees to return to work. This can also make your business more attractive to prospective hires, especially in majority-female industries such as veterinary medicine. Generosity builds trust and loyalty. If this is not an option, employees may purchase a short-term disability plan prior to becoming pregnant that will replace some of their salary. Many practices allow employees to use banked vacation and sick leave pay to help fund a maternity leave. Your policy should state whether employees can save unused vacation time from a previous year to use in a future year for a maternity leave.

7. How Long Should a Maternity Leave Be?
Your policy should consider the needs of your business as well as the needs of the postpartum worker. Most deliveries assume a 6-week postpartum period of disability (8 weeks for twins or triplets), and with complicated births this period may be longer. As a result, 6 weeks is considered a minimum time for maternity leave, and that is the time period covered by most disability policies. If your employee isn't able to return when expected, or requests additional time or a part-time schedule upon return, you should leave room in your policy for the possibility to extend leave when requested, subject to a review. If the employee has postdelivery complications, you might even be required to extend the leave, in order to comply with the ADA.

8. Is Maternity Leave Required?
Maternity leave is not a legal requirement for most practices, because most practices have less than 50 employees, so are not subject to the FMLA. However, with 85% of new veterinarians now female, having a policy in place is just good business. You also must provide disability leave for pregnancy or postpartum recovery if you provide leave for any other type of disability. In addition, the same benefits that are provided to workers on disability leave must be given to employees on maternity leave. This includes temporary disability benefits, accrual of seniority, pay increases, and vacation calculations. Employers must hold the pregnant employee's job open during their maternity leave for the same amount of time that jobs are held open for employees on disability leave.
The length of the maternity leave is based on the medical needs of the woman, and each individual case is different. Employees returning from a general disability or pregnancy leave are entitled to return to their former or a similar position at the same work schedule and pay, unless there is a legitimate business reason as to why that job is no longer available. Many states have laws requiring employers with fewer than 50 employees to provide leave of some kind, so researching your state’s requirements is important. If you have any questions about your obligation you should seek the advice of an attorney. Even if federal or state pregnancy laws do not apply to your practice, you may wish to provide pregnancy leave to attract and retain the best employees. When establishing a leave policy, just insure that it is administered in a way that is consistent and nondiscriminatory.

9. Summary
Veterinary medicine is a profession that employs many women of reproductive age. Consequently, it is extremely important that veterinary employers familiarize themselves with the laws that apply to their practice. Maternity leave equivalent to leave for other short-term disabilities must be offered to employees in order for a practice to be nondiscriminatory. Good business practices encourage the formation of generous leave policies for these valuable team members.

Acknowledgments

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

Conflict of Interest
The Author is a self-employed business consultant.

References
2. To be released in Spring 2018 – 2016 AVMA AAEP Equine Economic Impact Study.
Achieving Successful Employee Engagement, Team Collaboration, and Client Service through DiSC Training

Marsha L. Heinke, DVM, EA, CPA, CVPM

The key to a successful work life is the ability to communicate effectively and interact respectfully with others: coworkers and clients, supervisors, and direct reports. Savvy employers build healthy practice cultures through ongoing employee education and training that mitigates turnover of valuable employees and improves client service. DiSC instrumented learning is one excellent, affordable, and easy-to-implement tool that supports such human resource development. Author’s address: 934 Main St., Grafton, OH 44044; e-mail: mheinke@vpmp.net. © 2018 AAEP.

1. Introduction

The highly reliable and trusted human resource training tool of instrumented learning (DiSC) aids employee self-awareness and improved potential in collaboration, organizational success, and client service.

With 30 years of worldwide use across more than 40 million users, DISC® Classic has dozens of employee training and coaching applications.

Designed to complement and supplement existing training programs, DiSC helps employees improve communication, ease frustration and conflict, and develop effective managers and teams.

Some of the key areas of veterinary practice use include helping employees use innate preferences for best fit in their job positions, as well as diminishing communication lapses that impede efficient work performance and client service.

2. Discussion

Doctors of veterinary medicine are notoriously adept at interpreting animal body language. No wonder! We appreciate how the inherited survival mechanisms affect the behavioral response patterns of any animal, domesticated or wild. Should not the same recognition hold true with the people we work with every day?

Humans have their own behavior patterns that reflect an innate response to their environments, including work. Instinctive survival mechanisms can kick in, even for employees in the veterinary hospital setting. How people react and behave in response to the stimuli around them lends to their strengths in accomplishing tasks and getting the work done, as well as why employees may clash from time to time.

Yet, most practice owners and managers do not recognize these work styles as innate and somewhat hardwired, predictable reactions to the work environment that can be molded into positive interactions and activities that build the practice. Rather, they tend to focus on negative aspects of behavior. Fairly repetitive and similar stories of employee “problems” include: the territorial technician who...
runs off other nurses, the chatty receptionist who does not have an eye for the detail of a missing vaccine date, and the meticulous associate doctor who takes an hour with every client.

Employee teamwork can improve when leadership learns to appreciate employee diversity, and teaches and reminds coworkers about how differences help everyone do a better job. Differences in work and behavior styles are healthy. If we were all the same, it would be much more difficult to achieve the level of collaborative effort that meets the needs of clients and patients.

Human Motivation

Basic psychology applies to your work as human resource manager. A good starting point is to understand that all human actions are motivated. The people you work with do things (or do not do them) for their own reasons. Part of the reason is that each of us is genetically programmed for self-interest as a survival mechanism.

Often, we are totally unaware of the exact reasons we act or react in a particular manner. Under stress, we may automatically behave in the way that is most natural or typical for ourselves. We tend to rely on and exhibit similar behavioral patterns throughout our lifetime. In the veterinary hospital work setting, how we interact with each other is as much a result of each person’s natural behavior style as the work environment activity. The individual’s perceived position in the hierarchy of workplace organization impacts how that person will function.

As a practice manager or leader, you cannot always control how people react to situations. Although you may try to lead by example or coach employees, oftentimes you may find you simply learn how to cope with employee behavior styles that seem more detrimental than helpful.

To the extent possible, you may be able to adapt employee management approaches to fit each person’s needs. One strategy is to help employees through training and feedback by teaching them about their preferred work styles and natural reactions. The goal is to have employees better understand where their actions help achieve practice goals and where other behaviors are disruptive. Increasing self-awareness reduces the conflict caused when people are unaware of how their behaviors affect or seem to others.

Two people can perceive the same situation in totally different ways. This becomes a barrier to cooperation. If you could teach your employees to understand how each other tends to view what is happening around them, barriers break down and there is better communication about what each person is trying to accomplish in the situation.

We tend to be more aware of our strengths than our limitations. Learning about our weak areas allows us to improve in those less optimal reactions and interpersonal behaviors through conscious efforts. Sometimes, too, we overplay our strengths which results in less effective outcomes and possibly conflict with other coworkers.

Veterinarians and practice managers are keenly aware of how personality conflicts tend to creep into the day-to-day activities of veterinary practice operation. Conflicts can be reduced when everyone has a basic understanding of why people behave the way they do.

Instrumented Learning: The Behavior Assessment Tool

One fun, but very practical, tool to accomplish this objective is the behavior profile. These quickly self-administered assessments do not have right or wrong results but provide valuable information for employees to gain uncannily accurate insight to themselves and others. This is the first step in understanding and appreciating individual work style differences: the natural strengths and weaknesses any employee contributes to the veterinary practice.

Veterinary practices tend to become more effective and, as a result, more profitable when the individuals within the organization learn to appreciate the differences in each other’s work behavioral styles. Diversity allows for strength. Expressing appreciation of differences instead of criticism becomes an important step to improve your ability to lead and positively interact with the people around you.

Many companies market products and systems that are designed for teaching about predicted behavior. Commercially available systems use self-administered assessments to identify the natural behavior styles of people. The knowledge gained from consistently using behavioral profiling instruments helps facilitate employee training, interaction, and client service. In turn, a more enjoyable and profitable practice environment results.

Not Good or Bad, Just Different!

When using instrumented behavioral assessments, keep in the front of your mind that there is no such thing as a “good” or “bad” type. Each person is different, presenting a complex mix of innate factors and exhibited behavior that is only one aspect of personality, shaped by many contributing influences. Each person has natural attributes and strengths that another person may display differently in a similar situation.

Behavioral categorization is best used in the workplace setting to gain a better understanding of yourself and others and also to discover how your style affects others, both positively and adversely. Employees that embrace this concept can learn to modify or adapt their natural reactions and behaviors, so that the potential for conflicts is reduced. They also embrace acceptance and tolerance for different styles.

Ultimately, your goal is to develop your veterinary practice into a healthy, productive, positive-thinking culture. Dr. Ray Russell reminds us that we do not necessarily want to follow the golden rule in man-
aging a veterinary practice: “Do unto others as you would have them do unto you.” Once you understand behavior types, you can begin to understand that the best way to build relationships is to treat others as they would like to be treated because of their perception of the environment and of themselves. If you can remember to treat others as they would like to be treated rather than the way you would like to be treated, you are practicing the “platinum rule” of human relations.1

A Historical View of Four Temperaments

How many factors comprise personality still causes much controversy, even though the history of grouping personality into different groupings is quite ancient. Hippocrates described four types of temperament according to four body “humours” or humors: yellow bile, blood, phlegm, and black bile. Other ancient Greek and Roman thinkers furthered “humorism” by describing four temperaments: choleric, sanguine, phlegmatic, and melancholic. Humoral theory was the most commonly held view of the human body’s workings until advent of modern medicine in the nineteenth century.

Since Hippocrates’ time, many other researchers have described four groupings of personality or, more narrowly, behavior. William Moulton Marston described a model in the 1920s in his book, “Emotions of Normal People.” Marston described four basic human behavior styles called, “dominance, inducement, submission, and compliance.”

No person is purely one type of exhibited behavior style or another. People are a complex interaction of each of the four styles. Exhibited behavior is a result of a person’s perception of his or her relationship to others and the immediate environment, such as the veterinary hospital work setting.

No two veterinary practice environments are the same, in part because of the diverse nature of the people who work within them. Each practice has a unique and fluctuating environment due to the employee mix and hierarchy, leadership attitudes, practice culture, and client types.

Besides the impact of the veterinary workplace environment, employees tend to use their basic types of behavior patterns of the past, shown even as children. How a person behaves is based on three perceptions: of oneself, of the actions of other people, and of the environment. People tend to use the behavior pattern that is the most natural and comfortable for them, given these various perceptions.

Four Basic Styles

Using Marston’s model, consider each of the four styles: dominance, inducement, submission, and compliance. Each behavior style is best understood through realizing how the individual perceives himself in relationship to the environment.

Dominance

Individuals who are described as dominant perceive themselves as being more powerful than the environment in which they exist. They also view the environment to be potentially antagonistic or hostile. People who are based in this “negative universe” are more vulnerable to negative feelings than those who naturally have a positive outlook.

People who exhibit dominance tendencies use a very direct communication style. Others may perceive them as dictatorial and domineering. These individuals tend to have healthy ego strength and a “can-do” attitude. Individuals with more dominance tend to be goal oriented and like obtaining results. They enjoy a variety of work activities. They are motivated by new challenges and enjoy instigating change.

Inducers—Influential Behavior

Individuals described as inducing are like those in the dominance quadrant in that they perceive themselves as having control over the environment. They enjoy causing change and being in new situations. Unlike the dominance types, inducers perceive the environment as being friendly and supportive. Based in the “positive universe,” these individuals can also be described as being resilient in the face of change and stress.

People who have more of the inducement style tend to use their influencing strengths to work with others through persuasive skills and their sincere interest in other people. People who have inducement characteristics may be highly inspirational to others. Inducers enjoy social interaction with a wide variety of people.

Submissive—Working Cooperatively through steadiness

The third behavior style was originally called submission by Marston. These individuals are willingly following leaders as perceived allies for their greater good. This willing cooperation tends to create an environment of stability and steadiness.

Steadfast individuals tend to be loyal. They work well with other people because of their attitudes of cooperation. Steadfast individuals do not believe they have much control over the environment but do look at the environment as being supportive and friendly. Like those with the inducer behavioral style, they are more resilient being based in the positive universe.

Compliance—Quality Assurance through Conscientiousness

Marston described compliance as a response made to a superior force that dominated the situation. Today, conscientiousness is the word more commonly used to describe people with characteristics emphasizing this behavior style.

Conscientious people are concerned about quality control. They tend to pay greater attention to facts
and details. Correctness and quality of work product motivates them. Conscientious individuals view their control of the environment as being negligible. Vulnerably based in the negative universe, like the dominance style, they view the environment as being potentially antagonistic or hostile.

Recognizing Typical Behavioral Responses
A few other helpful observations provide insight to the four basic exhibited behavioral styles as described by Marston’s framework. People who have more dominance or compliance characteristics tend to see the environment as requiring either an aggressive or defensive response, because they view it as potentially antagonistic. On the other hand, those who have more influencing or steadfast characteristics tend to act in a more open and accepting manner.

Individuals with dominance or compliance characteristics tend to be more task-oriented. Their motivating goal is to obtain objectives and get the job done. The more dominance-oriented person may accomplish objectives by directing others and making quick decisive actions. The compliance/conscientious person may be more geared toward attention to details and consistent follow through of assignments.

Individuals who have more inducement or steadiness characteristics tend to be more interested in people and sharing experiences with others. They prefer building relationships and working with others rather than accomplishing specific tasks alone. Inducers like contact with a wide variety of people, in various social settings. Steady people have many long-lasting friendships and like to work with others in a team to cooperatively accomplish work objectives.

Good Starting Point for Implementation
You can now start to appreciate how understanding yourself and your employees in terms of these various characteristics could improve the ability to allow staff to get what they want out of work and to communicate more effectively with other people. For example, it is very common for someone with high dominance characteristics to clash with an individual based in conscientiousness.

The dominant person may be very direct, blunt, and to the point without giving much information. The conscientious individual, on the other hand, is motivated by doing things the right way the first time around. This person’s objective is to collect additional detail to assure the job is done correctly. The dominant person may be annoyed when the conscientious person asks questions to get more information. Since the dominant person uses a direct and possibly terse communication style that may be viewed as critical commentary, the conscientious person may perceive that s/he or the work product is being attacked.

The conscientious person may instinctively adopt a defensive attitude. The conscientious employee works hard to make sure everything is done correctly and is greatly offended by perceived criticism, which was really a neutral direct style normally used by the dominant individual.

In veterinary practice, many of the employees with whom you will be working may possess strong dominance characteristics. To our knowledge, no specific studies have been done to measure what percentage of veterinarians and technicians rank with the dominance category. Our personal experiences in performing behavioral profiles indicate that a very high number of these individuals do have strong dominance attributes. These characteristics are simultaneously beneficial and detrimental to practice operations: they result in quick and decisive task completion but with possibly not enough attention to interpersonal relationships. Coaching can help dominant people learn to soften their naturally direct and domineering communication styles.

Resource for Practice Management
As a part of personnel management protocol, consider evaluating and coaching individuals who will be working together. In a group situation, overall effectiveness can be increased in accomplishing tasks because relationships are improved among individuals within the practice unit. Use the information to develop strategies for working together to increase productivity.

The DiSC approach is one of many systems that are designed for teaching about predicted behavior. Commercially available systems use self-administered assessments to identify the natural behavior styles of people. The knowledge gained from consistently using behavior profiling instruments helps facilitate employee training, interaction, and client service. In turn, a more enjoyable and profitable practice results.

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

Conflict of Interest
Dr. Marsha L. Heinke, DVM, EA, CPA, CVPM, is shareholder and president of Marsha L. Heinke, CPA, Inc. which sells the DiSC® Personal Profile System® and related Everything DiSC® instruments (John Wiley & Sons, Inc.) as an aid to veterinary practice administrators, managers and owners.

Reference
This May Hurt a Little: Is Your Leadership Style Preventing Your Practice from Reaching Its Full Potential?

D.K. Eddleman, MHA

To reach its full potential, a practice must go through a series of life cycles, each requiring a different style of management. Frequently, otherwise-successful practices become stuck in a lifecycle because its founders are unable to adapt their leadership style to the changing needs of the practice. This paper will review a common condition known as Founder’s Syndrome and discuss ways to identify and treat it. Author’s address: 1410 Ellis Drive, Weatherford, TX 76088; e-mail: kirk.eddleman@inovapartners.com. © 2018 AAEP.

1. Introduction
In his book, Field Guide to Leadership and Supervision in Business, Carter McNamara, MBA, PhD, described Founder’s Syndrome, or FS, as “a condition in which an organization operates primarily according to the personalities of one or more members, usually the founders, rather than by the organization’s mission, policies and systems.” Put another way, FS is basically a lack of, or disregard for, formal organizational systems and structures to manage a practice. FS can involve one individual or a group of individuals who helped to start a practice or bring it through tough times such as periods of rapid growth. During these times, a business requires strong and passionate personalities who can make decisions quickly and motivate employees to action. Most veterinary practices are founded by determined, high-energy veterinarians who, while extremely skilled at practicing veterinary medicine and building a clientele, may not be good candidates for leading the practice as it evolves into a larger organization. The objective of this paper is to teach practice owners and practice managers how to identify the symptoms of FS and overcome it.

Identifying the Symptoms of FS
FS is frequently seen in practices that have grown quickly into large community powerhouses. These “foundered” practices often develop the following symptoms:

- A crisis-management approach to problem solving
- Cash flow issues from general lack of funds
- Strong resistance to change in the way decisions are made
- Nepotism
- High staff turnover
- Continual struggles around the same reoccurring set of issues.

NOTES
The Litmus Test
If you think you and your practice may be suffering from FS but you’re not sure, read the characteristics of FS below and see if any apply.

Common Characteristics of an FS-Infected Practice
To identify a foundered practice, one need not look much farther than the founders themselves. In an FS practice, the founders often:

- Inject themselves into routine operational decisions.
- Make reactive, crisis-driven decisions, frequently without seeking input from others or ignoring it all together.
- Count on and promote those employees who seem loyal and accessible, rather than on those with the best qualifications or talent.
- Handpick their employees, often like-minded friends or family members for key roles.
- See their employees as working for them (the founders) rather than working for the organization for which they (the founders) happen to be owners.
- Motivate employees through fear or guilt, sometimes even without realizing it.
- Have a difficult time letting go of the strategies that helped to quickly grow the practice.
- Are highly skeptical about planning, policies, and procedures.
- Criticize those who suggest the need for new rules and systems.

If you answered any of these apply to you, it may be time for an intervention.

2. Solution
Treating FS
If left untreated, FS can become a chronic and reoccurring condition that festers for years, slowly deteriorating the practice until the founders either leave, sell out, or the business simply collapses. The good news is that FS does not have to be fatal. If treated aggressively, the practice can recover and progress toward full maturity. Below are steps for treating FS.

1. Identify the Problem. The first and, by far, the hardest part of treatment is extreme self realization. In order to treat the problem, the founders must first recognize the need to change the way they lead and manage their practice. This means changing from within to better develop their own leadership abilities. Leadership and management are not the same thing. In fact, in many ways they are very different. Understanding that difference is critical.

2. Ask for and Accept Help. FS is the result of doing what comes naturally. Changing your own leadership style is difficult because it means changing what comes naturally. Finding an experienced mentor from outside the organization will help the founders understand their own management style and how their actions affect the practice. A good mentor can help guide the founders to becoming better leaders for their practices.

3. Develop the Board of Directors. While a good Board of Directors can be the great source of support in overcoming FS, a poorly developed Board will create a roadblock to success. A good Board should include people other than the founders and will focus on setting the direction for the practice. It will not be distracted by procedural or management issues. To be successful, Boards should meet regularly to:

a. Create and Review Strategic Plans. Strategic planning is the best way to engage the Board members and key employees in setting the course for the practice. Focus on two or three issues facing the practice in the next 3 months, 6 months, and 1 year and beyond and set realistic goals for the practice to achieve.

b. Conduct Risk-Management Exercises. Pretend one or more of the founders suddenly left the practice. How would operations be affected? What actions would management take? What would happen to cash flow? Who could step in? These kinds of “what-if” scenarios will help establish systems to manage the practice.

Board members should be given job descriptions and training focused specifically on the responsibilities of the board. All board members must understand their authority lies in the board room. Once outside the board meeting, established formal lines of authority must be followed.

Develop the Management Team and Systems. Appoint a team of individuals who will guide the practice and develop the management systems necessary to reach the goals set by the board. If current staff members don’t possess the experience and skills necessary to develop effective management systems, get help from outside the practice to assist. Once the management team is identified and systems are in place, it is crucial to ensure the founders do not revert back to their old habits and circumvent the systems that have been created or undermine the managers they appointed.

3. Results
Curing FS can be a painful process but the benefits of recognizing and handling the disease far outweigh the pain and hassle of treatment. Using appropriate channels, remind employees the problems associated with FS are the result of the practice’s success.
and growth. Once healed, employees will see stability and progress, morale will improve, customer service and the quality of patient care will improve, profits will grow, and the founders will sleep better, have more money in their pockets, and have more balance in their lives.

4. Discussion
For any business to grow it must continually change and adapt to meet the ever-changing needs of its customers and workforce. For a practice to grow from a startup business into a larger, fully developed company, it must go through several organizational phases or life stages. Each of these life stages requires a different style of management. In the early stages, the founders control everything, frequently making seat-of-their-pants decisions and using intuition to address the issues that come up. This style of management works when the practice is in its infancy. However, as the practice matures, the decision-making process must evolve to a more forward-thinking, collaborative style of governance. Internal control systems, lines of authority, company policies, standard operating procedures, formal budgets, and strategic plans must be developed and followed for the practice to advance towards its full potential. These transitions from one form of governance to another can be very distressing for the dynamic and visionary founders who worry that losing control of their practice will lead to certain failure. It is at this point that the practice is most vulnerable to FS.

As a practice grows, the demands for new and additional services increase, higher efficiencies and more resources are required and issues compound into serious problems. Not knowing what else to do, the flustered founders demand more from their employees who often take on additional roles and responsibilities for which they often are not qualified. Of course, that doesn’t fix the problems, because the problems aren’t caused by a lack of effort or ambition. Instead, they are results of employee confusion about their purpose and roles within the practice, and from the constant pressure from the founders to do better and more. Ultimately, no one understands what’s going on or who’s in charge. The good employees leave and those that remain either take on the traits of the crisis-driven founders, or worse, just “numb out” and continue to look to the frustrated founders for direction.

In these practices, the founders often see their business as one big “family” (with them at the head). Whenever problems arise, the founders make decisions as if they’ve gathered around the dining room table to make a decision that will help hold everything together. Interestingly, the practice may already have policies, procedures, and formal lines of authority in place, but because the founders are so confident in their own intuition and judgment, these formalities are ignored or viewed as unnecessary. The result is the practice becomes stuck in a never-ending cycle of reoccurring problems and underperformance. The practice is stuck in an immature life cycle.

It is important to note that FS is no one’s fault. The founders did not intentionally set out to harm their practice, nor is FS an individual problem. It is an organizational disorder that develops because the practice is dependent upon the founders for decision making rather than organizational systems and lines of authority.

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Reference
Testing for Endocrine Diseases in the Middle-Aged and Older Horse

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1. Introduction
Middle-aged and older equids comprise an increasing segment of the equine population as advances in health care maintain their athletic abilities and quality of life into their 20s and beyond. Because endocrine diseases are common and can be debilitating, it is important to screen for these conditions as part of routine wellness examinations. Certain conditions, such as equine metabolic syndrome (EMS), can occur in horses of any age, while pituitary pars intermedia dysfunction (PPID) is a disease of middle-aged and older animals. These two endocrinopathies are of most importance because both are associated with an increased risk of developing endocrinopathic laminitis. This crippling form of lameness occurs when hormonal abnormalities damage the sensitive tissues (laminae), anchoring the hoof capsule to the underlying bone. Weakened laminar tissues are unable to withstand the mechanical forces of locomotion, resulting in laminar disruption and displacement (rotation and/or sinking) of the distal phalanx within the hoof capsule.

2. Insulin Dysregulation
Insulin dysregulation (ID) is a metabolic derangement that can manifest as any combination of fasting hyperinsulinemia, postprandial hyperinsulinemia, exaggerated insulin responses to oral/intravenous carbohydrates, tissue insulin resistance, and dyslipidemia. ID is central to the pathogenesis of EMS and affects 30–60% of horses with PPID. Development of ID is the culmination of interactions between genetic, physiological, and environmental risk factors. ID can occur on multiple levels, from abnormalities in pancreatic insulin release to tissue insulin resistance. Hyperinsulinemia can develop because of enteroinsular axis over-activity or as a compensatory mechanism by the pancreas to override peripheral tissue insulin resistance through enhanced insulin output.

EMS and ID

The classic triad of abnormalities defining EMS includes: 1) generalized obesity and/or regional adiposity, 2) ID, and 3) clinical or subclinical endocrinopathic laminitis. Although most affected animals are obese, there is recognition of a lean phenotype; such animals might have increased adiposity of less visible internal fat depots that adversely affects metabolism.
Although abnormal adiposity and ID are associated, their relationships to one another are complex and incompletely understood in equids. In other species, obesity-induced adipocyte dysfunction creates a systemic proinflammatory state, with resultant disruption of postreceptor insulin signaling, insulin resistance, and compensatory hyperinsulinemia. Abnormal inflammatory states are inconsistently identified in obese horses, so the role of inflammation in equine obesity remains controversial. Other mechanisms, such as abnormal adipokine release, might play a more important role than inflammation in obesity-related ID in this species. For example, in the obese state, secretion of the insulin-sensitizing adipokine adiponectin is reduced.

EMS and ID also involve genetic components. Breed differences in innate insulin sensitivity have been demonstrated; insulin sensitivity is lower and insulinemic responses to carbohydrate challenge (oral and intravenous) are higher in some breeds. Insulin resistance and compensatory hyperinsulinemia are more easily triggered in these animals. Genetic differences in enteroinsular axis function may also promote heightened incretin responses to oral carbohydrates, with increased secretion of incretin hormones leading to higher postprandial insulin concentrations in affected animals. The enteroinsular axis consists of neuronal and hormonal factors (called incretins) released by the intestine that augment postprandial insulin secretion by stimulating pancreatic β-cells. In animals with overactive incretin responses, hyperinsulinemia can develop in the absence of tissue insulin resistance.

PPID and ID

PPID generally manifests in animals over 15 years old. The pars intermedia is normally under tonic dopaminergic inhibition by hypothalamic neurons; neurodegeneration leads to pars intermedia hyperplasia, microadenoma or macroadenoma formation, and uninhibited release of hormones from melano-tropes. The diseased pars intermedia secretes abnormally large quantities of proopiomelanocortin-derived peptides, including adrenocorticotropic hormone (ACTH), α-melanocyte stimulating hormone, corticotropin-like intermediate lobe peptide, and β-endorphin. Many of these hormones alter insulin and glucose dynamics, along with other aspects of metabolism.

There remains debate about the relationship between PPID and ID, as not all equids with PPID are affected by ID. One possibility is that they are independent conditions that can occur either individually or concurrently; identifying them together may simply represent the coexistence of two common endocrinopathies in the same animal. Alternatively, PPID may induce or exacerbate ID and hyperinsulinemia. Equids with concurrent PPID and ID (specifically, hyperinsulinemia) appear to be at the highest risk of developing laminitis.

Hyperinsulinemia in PPID-affected equids was originally attributed to the antagonistic effects of hypercortisolema on insulin sensitivity. However, understanding of PPID has improved and it is now known that cortisol excess is not the dominant feature of the disease in most animals. Pathologically high pituitary hormone concentrations are likely the more important drivers of ID. Corticotropin-like intermediate lobe peptide and other adrenocorticotropic hormone fragments act as insulin secretagogues in pancreatic β-cells. Heterogeneity in the severity of pituitary lesions, as well as individual variability in the specific proopiomelanocortin-derived peptide profile secreted by the diseased pars intermedia, might explain why PPID only induces ID in a subset of affected animals.

As in other species, insulin sensitivity decreases with age in horses and insulin responses to oral and intravenous glucose challenges are exaggerated. Because geriatric horses are already prone to heightened insulin responses, pathological conditions that exacerbate ID, such as PPID, might greatly increase their risk of developing hyperinsulinemia and endocrinopathic laminitis.

3. Endocrine Testing

Endocrine diseases can be assessed using either static or dynamic tests. Static tests evaluate resting hormone concentrations and represent an animal’s endocrine status at a single point in time. Dynamic tests involve a challenge, followed by assessment of the physiological endocrine response. Although fast and easy to perform, static tests are a screening tool. They are useful when abnormalities are identified, but lack sensitivity and can be normal in some animals with endocrinopathies. By contrast, dynamic tests perturb the system, which improves diagnostic sensitivity by overwhelming any compensatory homeostatic mechanisms that might be able to compensate in the resting state. The use of dynamic tests is recommended when possible, particularly in cases where mild endocrine abnormalities are suspected.

Static Tests of ID

Resting insulin concentration is frequently used as a screening tool, and hyperinsulinemia is suggestive of ID. Samples should be collected in the nonfasted state, with the animal receiving either its usual hay diet or pasture turnout; testing should be performed at least 4 hours after a concentrate (grain) meal. Resting blood insulin concentrations >50 µU/mL confirm the presence of ID, whereas those between 20–50 µU/mL are highly suggestive. Insulin concentrations <20 µU/mL are nondiagnostic, and it is recommended that dynamic testing be performed if clinical suspicion of ID remains. Resting insulin concentration is affected by factors such as stress, pain, systemic illness, and diet, so a result is more likely to represent a true positive the further it falls outside the reference range.
Although uncommon, overt type 2 diabetes mellitus also occurs, particularly in horses with PPID. In these cases, pancreatic insulin output declines due to β-cell exhaustion and glycemic control is lost. Hyperglycemia can be seen in conjunction with hyperinsulinemia or normoinsulinemia. Factors such as stress, pain, diet, and drug administration can cause hyperglycemia and must be considered when interpreting test results.

Dynamic Tests of ID
Because ID is a multifactorial condition, hyperinsulinemia and tissue insulin resistance can occur either independently or concurrently. Dynamic tests involving administration of an oral glucose challenge incorporate evaluation of the enteroinsular axis, whereas intravenous glucose challenges and the intravenous insulin tolerance test evaluate peripheral tissue insulin sensitivity. To obtain a comprehensive picture of the animal’s endocrine status, both types of tests may be performed concurrently.

Oral Sugar Test
Following a 3–8-hour fast, baseline blood insulin and glucose samples are collected, and then corn syrup (Karo® Syrup Light) is administered at a dose of 0.15 mL/kg orally using a dosing syringe. Additional blood samples are collected at 60 and 90 minutes for measurement of insulin and glucose. An insulin response >45 μU/mL supports the presence of ID, as it indicates increased β-cell responsiveness to glucose or decreased insulin clearance. Detection of hyperglycemia, particularly in the baseline sample, indicates diabetes mellitus. Fasting can be accomplished by providing the horse with a single hay flake the night prior to testing, with testing performed the following morning.

In-Feed Oral Glucose Test
After an overnight fast, baseline blood insulin and glucose samples are collected, and then dextrose powder is administered at a dose of either 0.5 or 1.0 g/kg in nonglycemic feed. Blood is then collected 2 hours later for measurement of insulin and glucose. An insulin response >68 μU/mL for 0.5 g/kg or >85 μU/mL for 1.0 g/kg is supportive of ID. Glucose concentration is measured to ensure that the meal was consumed and to detect diabetes mellitus.

Insulin Tolerance Test
Horses should not be fasted prior to testing. A baseline blood glucose sample is collected, followed by administration of 0.10 IU/kg regular (soluble) insulin intravenously. A blood sample is then collected 30 minutes later for measurement of glucose. Failure of glucose concentration to decrease to 50% or less of the baseline value is consistent with peripheral insulin resistance and decreased tissue responsiveness to the effects of insulin. This test carries a small risk of inducing hypoglycemia. If this occurs, 50% dextrose solution should immediately be administered intravenously at a dose of 0.1–0.2 mL/kg.

Combined Glucose-Insulin Tolerance Test
Baseline blood insulin and glucose samples are collected, followed by concurrent administration of 150 mg/kg of dextrose and 0.1 U/kg of regular (soluble) insulin intravenously. Another sample is collected 45 minutes later for measurement of insulin and glucose. Failure of glucose concentration to return to baseline by 45 minutes or an insulin concentration over 100 μU/mL at 45 minutes are indicative of peripheral tissue insulin resistance. As with the insulin tolerance test, there is a small risk of inducing hypoglycemia.

Static Tests for PPID
Measurement of resting endogenous plasma ACTH concentration is frequently used to diagnose PPID, particularly in equids with more advanced disease. This hormone is prone to rapid degradation, so proper sample handling is important. Plasma should be collected in a plastic ethylenediaminetetraacetic acid (EDTA)-coated tube, then spun and frozen within 4 hours.

Samples can be collected at any time of day and fasting is not necessary prior to testing.

When performing this test, appropriate seasonal reference ranges must be used, as ACTH concentrations normally increase from mid-July to mid-November as part of physiological processes that alter metabolism in preparation for winter. Horses with PPID retain this circannual fluctuation in ACTH concentration; in fact, the magnitude of the fall seasonal rise is more pronounced in PPID-affected animals, increasing the sensitivity of this test during the fall months. During non-fall seasons (mid-November to mid-July), resting plasma ACTH concentrations <30 pg/mL are considered normal, concentrations between 30–50 pg/mL are equivocal, and those >50 pg/mL support the presence of PPID. During the fall, these values are <50 pg/mL, 50–100 pg/mL, and >100 pg/mL, respectively. If normal or equivocal results are obtained, yet there remains a high clinical index of suspicion for PPID, dynamic testing is recommended. False positive results can occur with severe systemic illness, stress, pain, exercise, and transportation.

Dynamic Tests for PPID
Thyrotropin-Releasing Hormone Stimulation Test
Melanotropes of the pars intermedia express the thyrotropin-releasing hormone (TRH) receptor, and secretion of ACTH in response to TRH administration is exaggerated in PPID-affected animals. This test is performed by collecting a baseline plasma ACTH sample, followed by administration of either 0.5 mg (horses <250 kg) or 1 mg (horses >250 kg) of TRH intravenously. A second plasma sample is collected exactly 10 minutes later for measurement.
of ACTH. At the 10-minute time point, plasma ACTH concentrations <110 pg/mL are considered normal, concentrations between 110–200 pg/mL are equivocal, and those >200 pg/mL support the presence of PPID. Transient yawning, coughing, and Flehmen responses sometimes occur in response to TRH administration but are transient and subside within minutes. One limitation of this test is that there are currently no established fall seasonal reference ranges, so testing cannot be performed between mid-July and mid-November. Additionally, the TRH stimulation test should not be performed until at least 24 hours following the oral sugar test, as the latter blunts ACTH responses to TRH administration for reasons that are currently unknown.

### Overnight Dexamethasone Suppression Test

In the normal horse, 98% of ACTH is produced by the pars distalis, which is subject to negative feedback from exogenous glucocorticoid administration. Therefore, ACTH release and subsequent cortisol production should decrease following dexamethasone administration. In animals with PPID, the abnormal pars intermedia continues to produce ACTH because it is subject to negative feedback from exogenous glucocorticoids, so cortisol concentration fails to suppress after dexamethasone is administered. To perform this test, a baseline blood cortisol sample is collected in the late afternoon on day 1. Dexamethasone is then administered intramuscularly at a dose of 40 μg/kg. A second blood cortisol sample is collected between 15–19 hours later, on day 2. Failure of cortisol concentration to suppress to <30 nmol/L supports the presence of PPID. One limitation of this test is that it takes 2 days to perform, yet its sensitivity is comparable to measuring resting ACTH concentration, which only requires one sample. Another limitation is that fall reference ranges have not been established for this test.

### Acknowledgments

### Declaration of Ethics

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

### Conflict of Interest

The Author is a member of the Equine Endocrinology Group, which provides recommendations on the diagnosis and management of equine endocrine disorders; the Equine Endocrinology Group is supported by Boehringer Ingelheim.

### References

Endocrine Disease in the Aged Horse: Is It PPID, EMS, ID, or Just Plain Old?

Dianne McFarlane, DVM, PhD, DACVIM

1. Introduction
Endocrine disease in the horse can be difficult to diagnose, particularly early in the course of the disease. Yet, best practice dictates early diagnosis and intervention to avoid development of disease sequelae that can be career-limiting and life-threatening. Recommendations for what constitutes best diagnostic tests, appropriate reference intervals, and even clinical signs of disease have changed numerous times over the past 15 years. Thus, misdiagnosis and inappropriate treatment of endocrine disease are not uncommon in equine practice. Considering treatments are often lifelong and not inexpensive, a more accurate assessment of endocrine status would benefit both the patient and client.

2. Objective
The objective of this talk is to discuss a practical, rational, and holistic approach to reaching an endocrine diagnosis in the horse, based on the most current available data.

The key to diagnosis of endocrine disease in the horse is to use a holistic approach rather than relying on an isolated laboratory finding, static clinical signs, or signalment alone. Understanding the underlying pathogenesis as well as the secondary clinical syndromes associated with endocrine disease will aid in this approach. One can compare this to the approach for diagnosing sepsis in the foal. A positive blood culture is the gold standard diagnostic test. But in the absence of blood culture results, a composite score (known as a sepsis score) can be calculated incorporating multiple lines of clinical and laboratory data to increase the odds of arriving at a correct diagnosis. Although endocrine scoring systems that are similar to the sepsis scoring system are not yet available, the same principles apply.

3. Background: Understanding the Pathophysiology of Equine Endocrine Disease
There are two primary endocrinopathies that commonly affect adult and geriatric horses, equine metabolic syndrome (EMS) or insulin dysregulation (ID) and pituitary pars intermedia dysfunction (PPID). Equine metabolic syndrome by definition is a collection of clinical signs that predicts an increased risk for endocrinopathic laminitis. Of these signs, the central abnormality that confers risk of laminitis is ID, resulting in excessive insulin exposure. All horses with EMS have ID as the primary abnormality, and a diagnosis of EMS is dependent on demonstrating ID. Other signs, such as obesity, may or may not be present. The pathogenesis of
the ID may vary. However, regardless of its cause, the endpoint that puts these animals at risk of laminitis is increased insulin exposure. Understanding the different paths that lead to ID is useful as different diagnostic tests will produce different outcomes based on the underlying pathogenesis, as discussed in detail previously. For example, a thrifty pony may have excessive pancreatic insulin release after eating a meal high in simple sugars. An oral challenge test is needed to identify this problem. A test of tissue level insulin sensitivity, such as the insulin tolerance test (ITT) or the combined glucose ITT (CGITT) may or may not be abnormal.

The second common endocrinopathy of horses is PPID, an age-related disease that is the result of unregulated pars intermedia hormone release secondary to dopaminergic neurodegeneration of the hypothalamic neurons. This is a slow onset disease that affects horses starting in their late teens. Evidence suggests it is due to chronic exposure to damaging events, such as oxidative stress and accumulation of intraneuronal cellular waste products. A suggestion has been made that horses with ID/EMS are predisposed to PPID; however, there is no evidence to support this link as of yet. Genetics likely contribute to risk, as some breeds are suggested to be affected more commonly.

4. Components to a Holistic Diagnostic Approach to Equine Endocrine Disease

The holistic approach always starts with the animal, not diagnostic test results.

History and Signalment

History and signalment are extremely important when considering an endocrine diagnosis. Clinical signs of PPID and EMS wax and wane according to season, diet, and other environmental factors that influence hormone and metabolic regulation. Hair coat, body weight, and hormone secretion are affected by season and, therefore, what you see on a given day may not reflect the clinical signs that predated your examination. Therefore, a complete history is essential. Consider designing a history form for the owner that gathers information on shedding time, shedding completeness, body weight gain or loss, hoof health, exercise tolerance, sweating, urine output, and water consumption. What is the horse’s diet and exercise regime? What other problems have been observed? Has mentation and/or behavior changed? Consider sending the history form to the owner prior to the appointment to help keep the appointment efficient. Knowing historical details will help reach a clearer picture of the functionality of the horse’s endocrine system beyond what can be determined at a single point in time. The case in Figure 1 illustrates the importance of a complete history when making a diagnosis.

Several factors may influence body weight in horses suspected of having EMS. Horses that are being carefully managed for body weight due to a previous diagnosis of EMS may no longer be obese at the time of the veterinary visit. Horses with chronic laminitis will lose weight over time secondary to pain. In either scenario, the horse may still have ID and, therefore, should be tested based on historical findings. Some breeds of animals are prone to ID, even when body weight and nutrition are well managed. These are the so called “thrifty breeds,” and include mustangs, Peruvian Pasos, and ponies. Testing for ID in thrifty breed animals is recommended, even if weight is being well managed.

Signalment should also be considered when investigating a potential endocrinopathy. Thrifty breed horses should be considered at high risk for ID regardless of their current body condition. Careful evaluation of diet, hoof health, and assessment of insulin regulation should be performed in all thrifty horses with scheduled routine follow-up examinations in an effort to identify ID early and avoid endocrinopathic laminitis. In thrifty horses diagnosed with PPID, it is critical to also assess insulin regulation even if they are not obese, as animals...
with concurrent ID and PPID are highly susceptible to endocrinopathic laminitis, often with the additional complication of subsolar abscesses. Age is also an important indicator of risk of endocrine disease. The author does not make a diagnosis of PPID in horses younger than 14 years of age in the absence of strong supporting clinical and diagnostic evidence. There are several factors that can increase adrenocorticotropic hormone (ACTH) concentration other than PPID, making test results alone unreliable (see below). Thrifty horses will have a more profound seasonal activation of pars intermedia response than a nonthrifty horse. Both baseline ACTH and ACTH after thyrotropin-releasing hormone (TRH) administration may be significantly above the reference interval in easy keepers during the fall, without additional clinical or pathological signs of PPID. In other words, false positive tests for PPID are common in thrifty horses in the fall. Although these horses warrant close monitoring over time, the author would not choose to treat these horses as having PPID if their only clinical signs can be attributed to ID, such as laminitis, obesity, or regional adiposity.

Although a diagnosis of PPID in a horse younger than 14 years should not be made without strong additional evidence, PPID does occur in younger animals. In addition to the age-related typical PPID, there is a very uncommon, early onset PPID that likely has a strong genetic component. These early onset cases are most often rapidly progressing and, in the author’s experience, have clear clinical and diagnostic indications of PPID. The horse in Figure 1 was initially observed to shed abnormally at 11 years of age. Antemortem testing strongly supported a diagnosis of both ID and PPID, with an abnormal dexamethasone suppression test, plasma ACTH test, and serum insulin concentration. Diagnosis of PPID was confirmed at 13 years of age at postmortem examination by the presence of a Grade 5 pars intermedia adenoma.

Clinical Signs: What Are the Clinical Signs That Make You Suspect an Endocrinopathy?

Clinical signs: If obesity, regional adiposity, easy keeper, laminitis of unknown origin, or seasonal laminitis are the clinical signs, one should be concerned with ID.

A horse with any of these clinical signs needs to have objective and subjective measures of body weight, body condition, and regional adiposity as part of the examination. Body condition scores and neck circumference measures should be recorded in the medical record, along with a body weight either by scale or weight tape. Multiple measurement strategies are preferred, as the body condition scoring system is not as accurate in obese animals. Although obesity, either generalized or regional, is a primary clinical sign of EMS, not all horses with EMS are obese and not all obese horses have EMS. Therefore, one can think of obesity as a biomarker of ID and its presence should trigger one to perform a diagnostic test to assess insulin regulation to determine laminitis risk. Examination of hoof growth characteristics, hoof heat and pulse, hoof pain as assessed by hoof testers, and gait analysis should be part of the evaluation of horses with these clinical signs. Digital photographs are ideal for recording changes in hoof growth patterns. Hoof radiographs are highly recommended. Diagnostic testing to evaluate insulin regulation should include an oral sugar test and/or an assessment of tissue-level insulin resistance (e.g., ITT).

If an obese horse that is an easy keeper has a normal oral sugar test and/or a normal ITT, it may be a metabolically healthy obese horse or the test results may be a false negative. Either way, you are going to manage this horse similarly. Because it isn’t possible to determine if an obese horse with normal insulin regulation testing is going to progress to ID (is in a pre-ID, pre-EMS state), the most prudent approach is to consider this horse at higher than normal risk of laminitis. Work with the client to adjust diet and environment to facilitate weight reduction in the horse. A therapeutic plan will include dietary management, hoof care, and possibly pharmaceutical interventions, as will be discussed in a subsequent session. Monitor the horse with scheduled assessments of the insulin axis (OST or ITT) and full examinations of its feet, because both of these will help in establishing laminitis risk more than body weight or condition alone.

If this horse is young (<14 years) and has no clinical signs that are not a direct outcome of obesity or laminitis, then diagnostic tests for PPID may not be necessary, other than to provide a baseline. Testing for PPID should be included in the work up of all aged ID suspects or those with additional clinical signs that suggest PPID. This is critical because horses with concurrent ID and PPID are going to have a different treatment plan and a different prognosis with a greater risk of laminitis than those with either disease alone.

Clinical Signs: If an Aged Horse Is Shedding Abnormally, Then One Should Rule Out PPID

If a horse that is in its middle teens or older is shedding late, incompletely, or not at all, chances are that it has PPID and a laboratory test will support the diagnosis. These are not difficult cases to diagnose, although it may be necessary to perform a dynamic endocrine test (e.g., TRH stimulation test) earlier in disease progression.

Clinical signs: If the horse has less specific clinical signs including muscle atrophy, bacterial infections, changes in behavior, abnormal sweating, polyuria, infertility, exercise intolerance, ligament, or tendon injuries you might suspect early PPID.

A logical approach to diagnosis is critical to avoid mislabeling the horse with PPID, resulting in lifelong treatment or failing to treat a horse with true PPID.
PPID is a hormonal imbalance that causes muscle wasting and loss of body condition if untreated. Horses and ponies with obesity or regional adiposity (with or without laminitis) as the only clinical signs are much more likely to have EMS than PPID. Mild muscle atrophy or exercise intolerance is an expected consequence of aging and additional evidence should be present to diagnose PPID. There are many causes for infertility, exercise intolerance, and soft tissue injury beyond endocrine disease.

Diagnostic Approach Early in Disease

Early in the disease in horses with less specific clinical signs, it may be easier to rule out PPID rather than make a definitive diagnosis due to the poor sensitivity of the diagnostic tests in early cases. Start by looking for other causes of the identified clinical problem(s) and correct them. For example, in an older horse with weight loss, perform a detailed physical examination and blood analysis to rule out other systemic problems. Correct common causes of weight loss first, such as dentistry, diet, and intestinal parasites. If body weight does not respond once these problems are resolved, then PPID is more likely and testing is indicated. This approach is not dissimilar to how one might approach a high serum creatinine. Before exploring the diagnosis of kidney disease with invasive and expensive tests, the patient will receive fluid to correct prerenal causes of inadequate urine production. If serum creatinine is still high after common causes have been corrected, a more extensive work up of renal health is indicated. Endocrine testing can also be affected by the current state of the horse, such as chronic disease or malnutrition. In the horse with severe weight loss, it is important to recognize that very poor condition can increase ACTH concentrations due to stress of malnutrition (see Figure 2), so diagnostic test results may be misleading if performed before the common causes of weight loss are addressed.

PPID is a hormonal imbalance that causes muscle wasting and loss of body condition, not weight gain. In horses and ponies with obesity or regional adiposity (with or without laminitis) as the only clinical signs, think EMS. The author strongly recommends monitoring all horses with EMS closely as they age as there may be an association between EMS and later development of PPID and animals with both diseases fare worse than those with either disease alone. When testing an obese horse for PPID, it is important to recognize that thrifty animals are more likely to have an increased ACTH concentration before and after TRH administration, especially in the fall, thus limiting the usefulness of the diagnostic tests.

PPID is a chronic condition that may underlie development of secondary diseases. Older horses with recurrent bacterial infections should be tested for pituitary dysfunction, as age alone does not cause sufficient changes to the immune system to render the horses more susceptible to bacterial infections. Although there are many causes for reproductive problems in the older horse, if common causes of infertility are ruled out, consider testing for PPID. If an aged horse has no history of inappropriate sweating in a similar environment, development of an age-onset of hyperhidrosis or anhidrosis should cause one to consider PPID. In all of these cases, the indication for endocrine testing is based on a combination of history, signalment, and clinical signs for which other causes have been ruled out.

One approach to diagnose early cases is to use the diagnostic tests strategically to maximize their abil-
ity to discriminate between normal and diseased horses. Although there are no reference intervals for TRH stimulation in the fall, a normal resting ACTH concentration before or after TRH stimulation when performed between August 1 and November 1 (in the northern hemisphere) is strong evidence that the horse does not have PPID. ACTH concentrations are lowest in the spring, with the reported nadir occurring in April in the United Kingdom. Therefore, an ACTH concentration above reference interval during March to early May might be stronger evidence of pars intermedia dysfunction than at other times of the year. Establishing an individual patient’s normal values as part of a well horse screen when horses are younger can help identify earlier changes as they occur with age.

Why Diagnostic Testing Alone is a Poor Approach to Diagnosis:

- Thrifty animals are more likely to have an increased ACTH concentration before and after TRH administration, most dramatically in the fall.
- Ill or unthrifty horses may have high ACTH concentrations due to the stress of poor condition (see Figure 2).
- ACTH concentration may be increased in animals with chronic or acute disease. Early endocrine cases often test negative due to poor sensitivity of the diagnostic tests.
- Healthy aged horses have mildly higher plasma ACTH concentrations than healthy young horses.
- Gray horses have higher ACTH concentrations than nongray horses in the fall.

5. Summary

Diagnosis of endocrine disease in the horse requires an integrated consideration of signalment, history, clinical signs, and diagnostic test results. Many factors may affect hormone concentrations and, consequently, diagnostic test results for endocrine disease can be misleading if not considered in the context of the other factors.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

Dr. Dianne McFarlane has no conflict of interest. She has participated in the Equine Endocrinology Group that provides recommendations on diagnostic testing for PPID that is distributed by Boehringer Ingelheim (BI) in marketing handouts and in the Equine Endocrine Summit (a small group scientific meeting) both of which have been supported by BI.

References

The Intersection of PPID and Laminitis

C.M. McGowan, BVSc, MACVSc, PhD, DEIM, DipECEIM, FHEA, MRCVS

Introduction
Laminitis is a debilitating clinical syndrome of lameness due to hoof pain that equine practitioners are very familiar with. However, it has only been in the last decade that distinct causes of laminitis have been well defined and the importance of endocrine causes of laminitis, including laminitis associated with pituitary pars intermedia dysfunction (PPID) have been understood.1 This in-depth paper will discuss laminitis, focusing on endocrinopathic laminitis and the intersection of PPID and laminitis.

Causes of Laminitis
Research has stratified laminitis as occurring from 3 main causes: systemic inflammatory response syndrome (SIRS) or sepsis-associated laminitis including enterocolitis, pleuropneumonia, retained fetal membranes and grain overload; supporting-limb laminitis; and endocrinopathic laminitis.1

Historically, laminitis research was focused on conditions causing severe systemic inflammation (SIRS) or sepsis, such as carbohydrate overload or metritis. Notably, Obel’s 1948 thesis used both a starch overload and a metritis model to study laminitis.2 Between 1948 and the last decade, laminitis research involved exclusively SIRS models including starch overload,3 black walnut extract,4 and oligofructose overload.5 The severe SIRS or sepsis-associated form of laminitis was assumed to be more common, since it was more commonly seen at the university hospitals where most of the laminitis research had been conducted.6 Systemic endocrine disease was known to be associated with laminitis but received relatively little attention.7,8

Yet horse owners and frontline practitioners were telling a different story. In a large epidemiological study in the United States involving over 20,000 horses,9 it was found that causes of laminitis reported by their owners that were associated with SIRS or sepsis-related conditions including grain overload, retained placenta, colic, or diarrhea only accounted for 12% of the cases of laminitis, with the majority of cases reported as associated with dietary problems, obesity, or “unknown.” Studies in Europe10 and the United States11 showed convincing evidence that the endocrine disorders account for over 90% of horses presenting with lameness due to laminitis. The link between endocrine disease and laminitis was confirmed when researchers showed unequivocally that infusion of insulin induced laminitis in healthy, lean ponies12 or Standardbred racehorses.13 They also showed that infusion of glucose causing mild hyperglycemia and endogenous hyperinsulinemia resulted in laminitic hoof lesions (without lameness).14 This combined with some excellent field research looking at predispositions for laminitis in ponies in the United States15,16 all supported
the conclusion that laminitis could occur without pro-inflammatory and intestinal conditions; fitting with the term, endocrinopathic laminitis, that had been coined a few years earlier.17

Endocrinopathic Laminitis
There are two main conditions associated with endocrinopathic laminitis, PPID and equine metabolic syndrome (EMS). Common to both these conditions appears to be the development of insulin dysregulation. Insulin dysregulation results in hyperinsulinemia (either basally, or in association with the ingestion of carbohydrates in forages and feeds).18

PPID is a disease of aged horses characterized by loss of dopaminergic inhibition of the pituitary pars intermedia and resultant overproduction of pituitary hormones (adrenocorticotropic [ACTH], alpha melanocyte-stimulating hormone, beta endorphin, and corticotropin-like intermediate peptide [CLIP]). The resultant clinical syndrome is variably associated with a wide array of clinical signs including hypertrichosis and abnormal hair-shedding patterns, laminitis, muscle wastage, abnormal fat distribution, polyuria and polydipsia, increased susceptibility to infections, and infertility.19 EMS has been defined in the 2010 American College of Veterinary Internal Medicine (ACVIM) consensus statement as a phenotype of obesity (regional or generalized), insulin resistance (hyperinsulinemia or abnormal insulin and glucose regulation; now known as insulin dysregulation19) and a predisposition to laminitis that has developed in the absence of recognized causes such as grain overload, colic, colitis, or retained placenta.20

Laminitis and PPID
Laminitis has been frequently diagnosed in horses with PPID and laboratory submissions suggest it is a common trigger for horse owners to request veterinary investigation of cases of PPID.21 On pooled analysis from 13 studies, laminitis was the second most common clinical sign in horses with PPID (49%), second only to hypertrichosis (70%).22 Horses with PPID have 4.65 times the odds of developing laminitis compared with aged matched controls.23 Yet laminitis occurs variably in studies from 8% to 82%.22 This finding may seem conflicting, but can be explained by a number of factors.

First, it seems that insulin dysregulation is key to development of laminitis in PPID-affected horses. This is supported by histological research that showed that laminar lesions only occurred in horses with PPID and hyperinsulinemia, and not in horses with PPID but normal basal insulin concentrations.24 An epidemiological study demonstrated that over a third of horses with PPID had hyperinsulinemia, and 67% of horses with PPID and laminitis had basal hyperinsulinemia.23 Horses with PPID were 2.7 times more likely to have hyperinsulinemia than aged matched controls.23 However, when basal hyperinsulinemia occurred in PPID or non-PPID aged horses, they were equally at risk for developing laminitis.23

Secondly, even when horses are insulin dysregulated, laminitis may not produce clinical lameness. Histological research in naturally occurring cases of endocrinopathic laminitis showed no relationship between the duration of clinical lameness and the degree of pathology found histologically, but did identify the consistent presence of hoof capsular changes in association with the histopathology such as divergent hoof rings.25 This was supported by epidemiological research in aged horses where hoof abnormalities indicative of chronic laminitis (including dropped soles, laminitic rings, and separated white lines) were more prevalent than a history of laminitis.23,26 This implies that horses can have repeated subclinical bouts of laminitis without lameness, which may not be identified or may not be considered significant by horse owners.

Third, the presentation of horses with PPID for veterinary attention requires the recognition of the clinical signs of PPID by their owners. Epidemiological research has shown that many of the clinical signs of PPID are considered normal signs of aging by horse owners, including hypertrichosis and muscle atrophy.27 Indeed, in one study, only 1.6% of horse owners reported their horses with PPID, yet 21.2% tested positive on seasonally adjusted basal ACTH measurements.23 This may well explain the large category of “unknown” laminitis cases back in the 1990s when horse owners were asked to identify the causes of laminitis in their horses.9 Laminitis, at least where it causes lameness, is more likely to result in horses being presented for veterinary attention; therefore, if research studies or case series used owner-presented animals for inclusion in studies, the prevalence of laminitis is likely to be higher.21,22

Insulin Dysregulation and Laminitis
It is now well established that hyperinsulinemia associated with insulin dysregulation causes laminitis in affected horses, especially when challenged by dietary carbohydrates. Laminitis has been linked to insulin resistance and hyperinsulinemia in field studies since the 1980s.7,8,15,16,28 Experimental research has shown a direct link between hyperinsulinemia and laminitis.12,13 Laminitis was induced in 100% of normal ponies12 or horses13 exposed to high concentrations of insulin (> 1000 μIU/mL) while maintaining euglycemia of 5 mmol/L using a modified euglycemic-hyperinsulinemic clamp technique. All treated ponies or horses were healthy, young, and non-obese, with no history of laminitis and no evidence of endocrine or other abnormalities on blood tests. Laminitis occurred slowly and in all 4 limbs, with the onset of lameness associated with laminitis (Obel grade 2) occurring by approximately 48 hours. There was no evidence of gastrointesti-
nal involvement or systemic illness throughout the experiments.12,19

The hyperinsulinemic model of laminitis has allowed us to explore different mechanisms that are possibly involved in the development of endocrinopathic laminitis. Prior research does not support glucose deprivation26 or glucose excess27 as underlying mechanisms.

Metalloproteinases (MMP2 and MMP9 and ADAMTS4) have been consistently upregulated in SIRS or sepsis models of laminitis.31 However, this has not been the case in hyperinsulinemic laminitis where minimal MMP or ADAMTS4 activity during the developmental and acute stages of laminitis occurred and only MMP9 was upregulated at later stages of laminitis (48 hours), correlating with histological evidence of neutrophil infiltration.32

Mechanisms of Hyperinsulinemia and Laminitis

More recently insulin’s effect on signaling within cells and its effects on blood flow have provided important mechanistic clues. Insulin, when it is working via its appropriate intracellular pathways, has marked effects on stimulating vasodilation and blood flow in both small and large vessels via nitric oxide–mediated pathways.33 Insulin resistance results in inappropriate intracellular pathway activation leading to the opposite effects, which in the vascular endothelium leads to vasoconstriction. Ex-vivo vascular ring models from equine digital vessels showed that just 30 minutes pre-incubation in insulin (inducing insulin dysfunction) resulted in an inappropriate vasoconstriction response to the addition of insulin.34 This effect was obliterated by a blocker of the inappropriate intracellular pathway of insulin signaling.34

Further work in horse vasculature has supported this first study finding the same results using laminar vessels.35 This was further supported by comparing the vascular responses from naturally occurring endocrinopathic laminitis horses and controls using laminar arteries and veins and facial arteries.36 Vascular dysfunction was evident in the vessels derived from endocrinopathic animals but not the controls.36 Together there is now compelling evidence that hyperinsulinemia associated with either the hyperinsulinemia model or naturally occurring insulin dysregulation induces abnormal insulin signaling at a cellular level, at least in the vascular endothelium.

However, the vascular endothelium is only part of the story and does not correlate well with the histological lesion which provides even more important mechanistic clues.1 As early as 6 hours post exposure to hyperinsulinemia, marked elongation of the secondary epidermal laminae (SEL) is observed, developing tapered tips and with SEL angled more laterally19 and circulating cortisol may not be elevated why PPID may lead to insulin dysregulation includ-

ing abnormal central or peripheral glucocorticoid activity.17 Although much of the secreted ACTH in horses with PPID may be biologically inactive or inert39 and circulating cortisol may not be elevated in horses with PPID,41 there could be local upregulation of corticosteroids in peripheral tissues such as adipose tissue.17 Evidence for prolonged glucocorticoid administration inducing insulin dysregulation exists.42 Or it could be that pituitary peptides such as CLIP interfere with insulin regulation.19 But ultimately, the relationship between PPID and the development of insulin dysregulation is not completely known.

Irrespective of how horses with PPID develop insulin dysregulation, it is increasingly apparent that the combination of PPID and insulin dysregulation leads to a poorer prognosis than either PPID horses without insulin dysregulation43 or than insulin-dysregulated horses without PPID44.

Conclusions and Clinical Implications

Laminitis is a clinical syndrome with a cause, and endocrinopathic laminitis accounts for over 90% of laminitis cases seen in the field for lameness. Therefore, for laminitis that presents as lameness, clinical evaluation can often rapidly eliminate SIRS and sepsis-associated conditions and supporting limb laminitis as potential causes. If these are ruled
out, efforts to appropriately diagnose the underlying endocrinopathy should be made. Specifically, clinical examination and diagnostic testing can be used to determine whether the horse has EMS, PPID, or PPID with insulin dysregulation. Veterinarians should be aware that horses with PPID may not be presented with clinical laminitis or a history of laminitis, but hooves should be checked for evidence of subclinical laminitis in the form of divergent hoof rings, dropped soles, or separation at the white line) due to the possibility of these being missed by their owners.

It is important to assess insulin regulation in horses with PPID, as the presence of insulin dysregulation can guide determination of the likelihood of laminitis as well as the prognosis. Where insulin dysregulation is not well controlled, the prognosis for long-term survival is lower. Knowledge of the relationship between insulin dysregulation and laminitis can direct veterinarians to utilize the results of the diagnostic tests for insulin dysregulation (and PPID) to guide longer-term management.

VETERINARIANS should utilize the understanding of the early lesion of stretching due to cellular compromise in laminae to guide clinical management of horses with endocrinopathic laminitis. Management changes that should be considered include providing hoof support, thereby limiting mechanical forces and providing dietary and pharmacologic intervention to reduce circulating hyperinsulinemia as rapidly as possible.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

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References and Footnote


"McGowan CM, unpublished data."
Managing the Endocrine Aged Horse with a Focus on Those at Risk of Laminitis

C.M. McGowan, BVSc, MACVSc, PhD, DEIM, DipECEIM, FHEA, MRCVS

Introduction

Aged and geriatric horses are becoming increasingly important in equine practice, with referral hospitals documenting 5–10-fold increases in the proportions of geriatric patients over several decades.1,2 This is due, in part, to better veterinary diagnosis and treatment options but also is due to their owners presenting them for that care. Owners of aged horses are concerned about the health, welfare, and quality of life of their aged animals, which is often due to a deep human–horse bond that has developed over many years of ownership.3 Geriatric horses are owned for longer than younger horses,4 and surveys of management practices in epidemiological studies reflect a high level of owner dedication to these animals.5,6 Pituitary pars intermedia dys- function (PPID) is one of the more common geriatric diseases in horses, affecting over 20% of horses age 15 years and older, with an increasing prevalence with each subsequent year of age.7 Although PPID affects older horses, veterinarians should be aware of the importance of the aged animals to many horse owners when planning management options for them. This in-depth review will discuss the treatment and management of PPID, one of the most important diseases of aged horses, with a special focus on those cases with laminitis.

Initial Advice

Following a diagnosis of PPID, it is vital to fully inform the horse owner about the treatment options. Unlike a decade ago where conservative management was sometimes still advocated, medical treatment of PPID is now the accepted “norm,” and owners should have this option offered to them. As well as the availability of licensed medication, there is robust evidence supporting significant clinical and endocrinological improvements in more than three-quarters of PPID horses that undergo treatment8 and long-term improvements over many years have been maintained.9

During the initial explanation of the disease, it is important to ensure that horse owners are aware of the disease and understand its basic pathophysiology and how the treatment works. A comparison with Parkinson’s disease in humans or “accelerated aging” may be the best way to explain it to owners, helping owners to understand why a medical therapy might be appropriate. McFarlane10 suggests that the dopaminergic neurodegenerative process leading to PPID is associated with aging and has shown many similarities with Parkinson’s disease in humans. The neurodegeneration causes a loss of dopaminergic inhibition of the pars intermedia of the pituitary gland.11 The result is a loss of nega-
tive control of pars intermedia endocrine function and the overproduction of proopiomelanocortin-derived peptides produced by the pars intermedia melonotropic cells, including adrenocorticotropin (ACTH), alpha-melanocyte-stimulating hormone, beta endorphin, and corticotrophin-like intermediate peptide. This overactive pars intermedia becomes hyperplastic on histological examination initially and in more advanced disease can become adenomatous but is not a primary tumor like owners may assume.

Treatment
Medical treatment of PPID involves daily oral administration of pergolide, a dopamine agonist, which is licensed (FDA approved) for use at a dose from 0.002–0.01 mg/kg PO q 24 h. Treatment should be initiated at the low end of the dose range (to the nearest 0.5 mg) and gradually increased, if required, based on clinical and endocrinological response.

<table>
<thead>
<tr>
<th>Body Weight</th>
<th>Starting Daily Dose</th>
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<tr>
<td>200–350 kg</td>
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<tr>
<td>350–600 kg</td>
<td>1.0 mg</td>
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<tr>
<td>601–850 kg</td>
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Side Effects
Although pergolide has few specific side effects, up to one-third of treated horses will demonstrate transient inappetence on pergolide and around 10% may appear dull or lethargic. These side effects, especially inappetence, were more common when pergolide was first used at much higher initial doses. Therefore, careful attention to gradual increases of the dose can reduce the occurrence of these side effects. If signs of inappetence or depression are observed, the dose can be reduced by increments of 0.001 mg/kg BW or stopped for a short period (2–3 days or until appetite returns) and the dose restarted at half of the original dose.

Interestingly, when pergolide was administered in target animal safety studies, depression and/or anorexia were not observed in normal horses, even at doses as high as 0.008 mg/kg for 6 months. There were decreases in heart rate variably between geldings and mares but only to the normal range. Further research using normal horses in a blinded controlled crossover design trial with more detailed heart rate observations using Holter monitor recording at rest, during stimulation, and exercise did not demonstrate a difference in heart rate between groups.

Despite the frequency of side effects, it is important to recognize that signs of inappetence and lethargy are nonspecific and may accompany many diseases. Aged horses, even without PPID, have an increased risk of concurrent disease, so on identification of these clinical signs, especially if they don’t rapidly resolve with a reduction of dose, it may also be pertinent to investigate for concurrent disease.

Monitoring
Notwithstanding the improvements that most horses can expect from medical treatment, owners need to be aware that treatment is not curative, and medical treatment is a commitment that should be continued indefinitely, with monitoring, dose adjustments, and ongoing care as important parts of therapy.

General Health Monitoring
Most horses with PPID will be in their “teens” or older, with an increasing likelihood of diagnosis every year after 15 years of age. Aged and geriatric horses have an increased susceptibility to a range of conditions and diseases, particularly dental disease (including periodontal disease), lameness, eye conditions, heart or lung conditions, and skin conditions (including tumors such as sarcoids and melanomas). PPID may increase the risk of intestinal parasitism but does not alter a routine hematological or biochemical profile. Despite an association between alterations in blood tests and PPID being reported, it is important to note these have only been found in case series and not field-based epidemiological research. Case series rely on horses presented for veterinary care and, hence, suffer from owner bias. As noted in the companion paper on this in-depth session, epidemiological research has shown that many of the clinical signs of PPID are considered normal signs of aging by horse owners, including hypertrichosis and muscle atrophy, so owners may inadvertently delay presentation for veterinary care until concurrent disease occurs. Therefore, alterations in blood tests and concurrent illnesses should be investigated as concurrent disease, not ignored or presumed only associated with PPID.

In the aged population of horses presenting with PPID, there is a greater possibility of serious dental problems as well as periodontitis and diastema than in younger horses, so dental work should be carried out with veterinary care, including sedation, pain relief, and anti-inflammatory or other medication as necessary. If owners are fully informed of the high prevalence of these conditions in their horses’ age bracket and engage in regular health checks with appropriate blood testing, then the best outcomes can be achieved.

Monitoring Clinical Signs of PPID
Improvements in clinical signs are important monitoring tools and attention should be paid to trying to collect these as objectively as possible rather than just relying on endocrine “numbers.” Body condition score (and muscle score), hair coat, demeanor, appetite, Obel grade of lameness if lame (or evidence of subclinical laminitis like laminitic rings, widened white line, or dropped soles if not), and water intake can all be monitored. Baseline values should be obtained in consultation with the owner, then sub-
sequently horse owners can be encouraged to monitor and record these monthly.

**PPID Endocrine Monitoring**

Endocrine monitoring should include both monitoring of PPID as well as monitoring for the risk of laminitis. Testing for endocrine disease in the middle-aged and older horse is covered in detail in a companion paper in this in-depth session, but monitoring is achieved by repeating the endocrine testing used for diagnosis. For example, if basal ACTH was used for diagnosis, this value can be used as the baseline ACTH for follow-up evaluation of response to treatment. The first follow-up for a horse starting treatment for PPID should be within 4–6 weeks. At this time, ACTH values should have decreased substantially (e.g., by at least 50%) or be within the normal reference range, bearing in mind the seasonal increase in ACTH from late summer.

Although clinical signs may take longer to respond, most owners will detect an improved, brighter demeanor of their horse within this first time frame. If clinical or endocrine improvements are not noted, increase the dose of pergolide by 0.001–0.002 mg/kg BW/day, to a maximum of 0.01 mg/kg. Each increment in dose should be monitored with follow-up assessments of clinical signs and endocrinological testing similarly (within 1–2 months) until the horse stabilizes. If clinical signs have stabilized for more than 3 months on a dose higher than 0.002 mg/kg/day pergolide, a decrease of the pergolide dose by 0.001 mg/kg BW/day can be attempted, with the aim to reduce the dose back down to 0.002 mg/kg BW/day, bearing in mind that lower doses can result in treatment failure.

Once a suitable dose has been determined, follow-up monitoring can decrease to 1–2 times a year. Where twice-yearly monitoring is able to be performed, one of these follow-up tests should be timed to occur during September when there is peak ACTH and maximal sensitivity for diagnostic testing, bearing in mind the natural stimulation may push even a well-controlled horse a little outside of the seasonal reference range.

**Monitoring for the Risk of Laminitis**

In addition to monitoring PPID, it is also worthwhile to measure insulin dysregulation, either basally or dynamically, and this is imperative in horses with a prior history or current laminitis, including the presence of laminitic hoof changes. In horses with PPID, hyperinsulinemia is highly associated with laminitic lesions and laminitis. The presence of hyperinsulinemia is an important prognostic indicator for PPID survival overall, and the degree of insulin dysregulation provides a good indication of the risk of laminitis. Basal or dynamic (response to oral glucose or corn syrup) tests for hyperinsulinemia are recommended. The timeframe for monitoring hyperinsulinemia can usually fit in with ACTH monitoring, but in some cases with poorly controlled laminitis, yet well-controlled ACTH, it may need to be more frequent.

**Management of the Insulin-Dysregulated PPID Horse (at Risk for Laminitis)**

Insulin-dysregulated horses should be managed to reduce hyperinsulinemia, but care should be taken not to treat them exactly the same as horses with equine metabolic syndrome (EMS) without PPID. Prognosis is better in horses with controlled insulin dysregulation, even if this is unable to be completely normalized. However, some advanced cases of PPID with insulin dysregulation can prove difficult to manage, even in the face of normalization of ACTH concentrations. In these cases, management of the insulin dysregulation by using careful dietary control is advised.

**Dietary Considerations**

Tailored dietary restriction and exercise has been shown to improve insulin dysregulation in horses with EMS but can be less effective in horses with both PPID and insulin dysregulation. In one study, horses with both PPID and insulin dysregulation had a greater degree of insulin dysregulation and poorer response to dietary management than horses with insulin dysregulation only. Horses with PPID are already at risk for muscle atrophy, most likely as a result of muscle catabolism, so dietary consideration should focus on the insulinemic response to feeds rather than on management of obesity and weight loss. In the author’s opinion, even in obese PPID-affected horses, weight loss should be carefully monitored and reductions of 0.25–0.5% BW per week should be the maximum. Where persistent hyperinsulinemia exists, basally or dynamically, it is important to focus on the carbohydrate content of the diet, especially the non-structural carbohydrate content of the forage component, which often forms the bulk of the diet.

Soaking hay is a good way to reduce water-soluble carbohydrate content of hay and produces dramatic reductions in the insulinemic responses to forage in both normal and insulin-dysregulated ponies (without PPID), but soaking also results in leaching of water-soluble minerals (especially sodium, chloride, potassium, calcium, phosphorus, magnesium, and sulfur), so careful attention to appropriate balancing of the diet is recommended. Similarly, although protein is not lost by soaking hay, where horses are on a forage-only diet where protein content can be marginal, careful attention to protein (especially high quality amino acid supplementation) and vitamin and mineral supplementation is important to prevent and reverse muscle loss and atrophy.

In horses with more marked weight loss or unable to cope with long fiber, for example, due to dental disease, low-glycemic short fiber or complete rations can be purchased. Higher fat rations provide a

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high density caloric source and tend to induce lower insulinemic responses when fed.

Further Treatment
In some cases, pharmaceutical management with drugs such as metformin may help, although evidence supporting their effect on reducing hyperinsulinemia is limited.\textsuperscript{13} Exercise, as long as it is not limited by concurrent orthopedic disease or laminitis, is also useful to improve insulin dysregulation in horses with PPID.

2. Conclusions
PPID is an important disease of aged and geriatric horses. Although PPID affects older horses, veterinarians should be aware of the importance of aged animals to many horse owners when planning management options for them. There is now good evidence to suggest at least 75\% of treated horses should respond to therapy, including advanced cases. Less advanced cases (and some advanced ones) can return to athletic function and even competition-level activity, although competing on pergolide is still not allowed in many events, so this should be checked before competition. Notwithstanding the improvements that most horses can expect from medical treatment, owners need to be aware that treatment is not curative, and medical treatment is a commitment that should be continued indefinitely. Monitoring and ongoing care are important parts of therapy. Monitoring for clinical signs of PPID will help inform dose adjustments, and monitoring for and treating concurrent disease will lead to optimal outcomes. Endocrinological monitoring for PPID is important to direct appropriate dose adjustments and endocrinological monitoring for insulin dysregulation and will inform about the risk of laminitis and overall prognosis.

Acknowledgments

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

References and Footnote


27. McGowan CM, Unpublished data.


*Prascend, Boehringer Ingelheim, St. Joseph, MO 64506.*
How to Workup and Diagnose Respiratory Problems Related to Poor Performance in Race and Western Horses

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1. Introduction
Dysfunction of the respiratory tract is a major cause of poor performance in the equine athlete. Respiratory function is the main constraining factor to maximal work level in the fit, sound horse. Mild upper airway obstruction or lung disease can markedly diminish performance. Oxygen consumption in a horse at maximum exertion is about 40 times the value at rest. To meet the oxygen demands of working muscle, both respiratory rate and tidal volume increase markedly, resulting in an exponential increase of airflow through the upper respiratory tract (URT). Peak airflow increases from around 4 L/sec at rest to over 75 L/sec during exertion. The URT must be dilated and remain rigid during exercise to withstand the extreme negative and positive pressures required to move air at that rate. The nasopharynx and larynx are not rigid tubes; they are highly movable structures that perform diverse functions, such as breathing, vocalization, and swallowing. These complex movements depend on the coordinated contraction and relaxation of intrinsic and extrinsic muscles. A distortion of normal anatomy or impaired neuromuscular function can lead to narrowing or collapse within the URT during exercise. A relatively minor decrease in airway diameter results in a marked increase in resistance to airflow.

2. History
When a patient is presented with a complaint of poor performance, the history can raise the index of suspicion toward the respiratory tract as the likely cause. It can help to create a list of differential diagnoses within the respiratory tract. A thorough, accurate history is essential to formulate a plan and to select the appropriate diagnostic procedures. The effects on performance should be questioned. Has the level of performance actually decreased, or has the horse always performed below expectations? What is the level of training/fitness? Have there been changes in occupation or work load? Does the horse display exhaustion, elevated respiratory rate, or prolonged recovery after working? Are there any behavioral changes? Some horses with a respiratory condition will work to the point of collapse from hypoxia. Others will attempt to avoid hypoxia by decreasing their effort level or by displaying objectionable behavior when they are asked to perform. Any history concerning previous diagnostic procedures, treatment, or attempts to modify training is...
valuable. What has been done, when was it done, and what were the results? Are there any problems with chewing or swallowing? Is there any history of bleeding (e.g., exercise-induced pulmonary hemorrhage [EIPH]) if so, has the frequency or severity increased? Does the horse compete on furosemide or other medications?

In most cases of upper airway obstruction, an abnormal respiratory noise is observed during exercise. Lung conditions are not associated with abnormal breathing sounds during work. However, false negatives for respiratory noise occur. URT obstruction can sometimes present without accompanying abnormal sound. Abnormal sound can be “drowned out” by ambient noise (pounding hoofs, loudspeakers, machinery, spectators). The rider or trainer can often answer questions more accurately than the owner. An abnormal noise may not be noted until the horse pulls up. If possible, the character (whistle, gurgle, flutter) and timing (inspiration vs. expiration) should be ascertained. Billowing of the cheeks or mouth breathing can occur with soft palate displacement. Sudden palate displacement during exercise can cause an abrupt, dramatic decrease in performance. If an abnormal noise is not heard constantly, when during the exercise does it occur? Does it coincide with a change in performance? Does it seem to be related to certain conditions or maneuvers? Does head position (poll flexion or collection) change the noise? Is coughing or nasal discharge observed? Does the horse sweat normally? Tachypnea and exercise intolerance can be seen with anhidrosis in hot climates. The owner or agent should be asked whether lameness or stiffness is observed during or after work. Musculoskeletal pain can cause tachypnea, poor performance, and behavioral changes.

3. Physical Examination

Even with a history suggestive of a respiratory problem, a cursory exam for lameness and neurologic deficits should not be omitted. At minimum, the horse’s movement is evaluated at the walk and trot, in a straight line, and in circles. In the standing horse, the entire musculoskeletal system should be checked for swelling, atrophy, asymmetry, tenderness, and heat. During the physical examination of the respiratory tract, symmetry of air movement through both nasal passages should be confirmed. If nasal discharge is seen, it should be characterized and the source of the exudate should be pursued. The face and head should be checked for external swelling or asymmetry of the nasal and sinus regions and for evidence of cranial nerve deficit. The larynx and trachea should be thoroughly palpated. Laryngeal palpation is an acquired skill, but with practice, one can become accurate in detecting asymmetry of the caudal portion of cricoarytenoideus dorsalis muscles (CADM) secondary to recurrent laryngeal neuropathy, as well as hypoplasia or abnormal position of the muscular process of the arytenoid cartilage secondary to laryngeal dysplasia. The common sites for URT surgery should be checked for previous incisions. Laryngoplasty scars are difficult to detect without clipping the hair from the site. The trachea should be checked for indentation or deformity of the cartilage rings from injury or previous tracheotomy. The jugular veins should be checked for patency. Jugular thrombosis or phlebitis can be associated with vagal or recurrent laryngeal nerve injury or can cause nasal mucosal swelling. The trachea, heart, and lungs should be thoroughly ausculted.

4. Endoscopic Exam at Rest

A resting endoscopic exam of the URT remains the starting point for diagnosis of airway obstruction. Structural abnormalities can be assessed, as well as some functional deficits. Accurately predicting how an abnormality seen in the resting horse affects breathing at exercise can be problematic. The endoscopic examination should be performed without sedation. Sedation can cause asynchronous movement or incomplete abduction of the arytenoid cartilages. Horses are also more likely to show some degree of pharyngeal collapse at rest when sedated, especially when the nares are manually occluded. Most horses need some physical restraint to be scoped safely, most often accomplished with a rope twitch. A set of stocks provides additional protection to personnel and equipment if available. A complete examination includes visualization of both right and left nasal passages, ethmoid and nasomaxillary regions, nasopharynx (including soft palate), guttural pouches, larynx, and trachea. The nasal passages are best assessed as the scope is withdrawn. Narrowing of either nasal passage can occur with sinus disease or with enlargement or deviation of the nasal septum. Anatomic narrowing of the nasopharynx at the level of the guttural pouch openings can predispose the individual to lateral pharyngeal collapse at exercise. Pharyngeal lymphoid hyperplasia (pharyngitis) is commonly seen in young racehorses. Severe pharyngitis does not directly cause noise or obstruction, but affected horses are more prone to soft palate instability or pharyngeal collapse. The interior of both gullet pouches should be examined for empyema, mycosis, and enlargement of retropharyngeal lymph nodes. These conditions can affect function of the soft palate by causing neuropathy of the vagal and/or glossopharyngeal nerves. Nasopharyngeal cica-trix, subepiglottic cysts, pharyngeal cyst/ mass, persistent soft palate displacement, persistent aryepiglottic entrapment, epiglottic abscess or deformity, laryngeal hemiplegia, arytenoid chondritis, and tracheal stenosis can all be accurately diagnosed by standing endoscopy. Intermittent dorsal displacement of the soft palate (iDDSP) or palatal instability (PI) cannot be diagnosed by endoscopy at rest. Hypoplasia or flaccidity of the epiglottis does not correlate with increased likelihood of iDDSP or
PI at exercise. Ulceration of the caudal margin of the soft palate is suggestive of iDDSP at exercise or concurrent subepiglottic ulceration. Nasal occlusion during standing endoscopy can increase negative and positive pressures in the upper airway to levels approaching pressures reached during exertion. However, horses that display obvious dynamic collapse of one or more structures during exertion will usually be normal during nasal occlusion while standing. Nasal occlusion can be used to stimulate maximal abduction of both arytenoid cartilages in normal horses. DDSP induced by nasal occlusion at rest increases the likelihood iDDSP is occurring at exercise in horses with a history of abnormal noise at exercise. A combination of nasal occlusion and poll flexion during standing endoscopy can be used to increase suspicion that pharyngeal collapse is occurring at exercise. If asymmetric dorsal pharyngeal collapse is seen during poll flexion, subclinical guttural pouch tympani is suspected.

Standing endoscopy performed immediately after strenuous exercise may be advantageous. This procedure is common at racetracks, primarily to look for exercise-induced pulmonary hemorrhage or tracheal exudate. Some veterinarians and trainers believe DDSP seen immediately postexercise is an important finding, but correlation with dynamic endoscopy findings is lacking.

Recurrent laryngeal neuropathy can be assessed by endoscopy in the resting horse with acceptable accuracy. The ability to fully abduct the arytenoid cartilages is assessed and graded. The Havemeyer grading system has been well established and fairly accurately predicts the degree of airway compromise in the exercising horse. RLN normally involves the left side, so grading generally refers to abduction of the left arytenoid cartilage. Grade I denotes complete, symmetrical movement of left and right arytenoids. Grade II has asynchronous movement, but full abduction can be achieved and maintained. Grade III.1 has asynchronous movement and can’t maintain full abduction. Grade III.2 can’t fully abduct the left arytenoid. Grade III.3 has minimal abduction but some movement remains. Horses with Grade I or II should have normal arytenoid function at exercise. Horses with subgrades II.1, II.2, and II.3 will predictably have an increasing degree of arytenoid and vocal fold collapse at exercise. Horses with complete left arytenoid paralysis (Grade IV) will inevitably have severe airway compromise at exercise.

5. Dynamic Endoscopy

Endoscopic examination of the URT during exercise is the gold standard for diagnosis of upper airway problems. Many conditions affecting performance will only manifest during strenuous exercise. Airway pressures, geometry of the respiratory tract, and the coordinated contraction of the many muscles needed to breathe properly while running cannot be duplicated during an exam at rest. Dynamic endoscopy was pioneered in the 1980’s by using video-endoscopic URT examination during intense exercise on a high-speed treadmill (HSTE). The endoscopic exam is recorded and then replayed later in slow-motion for evaluation. Over the past 10 years, overground endoscope (OGE) systems have become commercially available, and OGE has become the prevalent method for dynamic endoscopy. HSTE allows the veterinarian more control over the horse’s workload so that the necessary exertion level and duration to reveal the problem(s) are achieved. However, HSTE facilities are not widely available due to the expense to build, equip, and maintain. The horse must be transported to a facility that offers HSTE and must be acclimated to treadmill exercise. Although injury is infrequent, the HSTE poses more risk to the horse than an OGE exam. OGE equipment is less expensive than a HSTE facility and can be easily transported to the horse where it trains or competes. The addition of tack and rider action can much more closely duplicate the conditions of competition. However, the veterinarian must insure that the horse is worked strenuously to match the intensity of competition. Race trainers may be resistant to have the horse work in company at near-racing distance due to risk of injury or interference with the horse’s training schedule. The rider should reproduce the conditions that manifest the problem (head position, speed, maneuvers). There is a learning curve to properly place and secure the OGE so that a diagnostic image is obtained. Technical problems including mucus accumulation on the end of the scope, movement of scope during the workout, or electronic malfunction, can invalidate the exam and lead to frustration. However, the expense, inconvenience, and work required are justified by the valuable information that cannot be obtained by other means. Dynamic endoscopy is indicated in cases with reduced performance and respiratory noise when resting endoscopy is normal or findings are of questionable significance. It can also be useful in some cases with exercise intolerance and no noise, but in many of these cases, no URT abnormalities will be found. Several important causes of URT obstruction can only be definitively diagnosed by dynamic endoscopy, including iDDSP, PI, vocal cord collapse, arytenoid cartilage collapse, axial (medial) deviation of aryepiglottic fold(s), nasopharyngeal collapse, epiglottic retroversion, intermittent aryepiglottic entrapment, and tracheal collapse. Only 26% of cases diagnosed with iDDSP in one study had any evidence of palate dysfunction on resting exam. However, the group found good correlation between resting and dynamic exams in predicting laryngeal function at exercise. Nearly half of cases examined had multiple abnormalities that were only seen at exercise. Even when a presumptive diagnosis can be made with resting endoscopy, omission of a dynamic exam can cause other important concurrent problems to go undiagnosed and untreated. A dy-
dynamic exam can be very important to investigate postoperative patients that continue to make noise and perform poorly. In spite of all the diagnostic capabilities of dynamic endoscopy, a cause of respiratory obstruction may be missed if it only occurs intermittently. Sometimes during the OGE exam the rider will not hear the noise the horse has been making and the horse displays no exercise intolerance. The exact conditions that correlate with collapse or obstruction cannot always be duplicated.

6. Laryngeal Ultrasound

Transcutaneous ultrasound of the larynx enables structural assessment of the laryngeal cartilages and muscles in addition to endoscopy findings. An ultrasound exam can be used in combination with endoscopy at rest to distinguish between RLN, arytenoid chondritis, and laryngeal dysplasia. Ultrasound equipment suitable for tendon imaging provides adequate penetration and resolution for an examination of the larynx. Arytenoid chondritis can usually be diagnosed by endoscopy, but ultrasound can provide clarity in cases with endoscopic findings of reduced arytenoid abduction and questionable changes in cartilage size or shape. In chondritis cases, ultrasound will show increased thickness and abnormal shape of the arytenoid cartilage, as well as hyperechoic foci within the normally homogenous cartilage matrix. The laryngeal muscles should have a normal appearance on ultrasound exam, unless concurrent neuropathy exists. With RLN, the cricoarytenoideus lateralis muscle (CALM) loses innervation in concert with the CADM. As nerve function deteriorates, both the CALM and CADM develop a homogenous hyperechogenic ultrasound appearance that is due to replacement of muscle fibers by collagen. Because the CALM changes appear early with RLN and that muscle is easier to image with ultrasound, the clinician can use the hyperechogenic appearance of the CALM as a reliable indicator of RLN. The opposite CALM and arytenoid cartilage can be used as normal controls, assuming the condition is unilateral. The abnormal CALM appearance correlates well with a diagnosis of arytenoid cartilage collapse during dynamic endoscopy. Therefore, dynamic endoscopy is not usually necessary to confirm RLN if endoscopy at rest and CALM ultrasound are abnormal.

Laryngeal dysplasia (also called 4th branchial arch defect) is a congenital malformation of the larynx that can appear identical to laryngeal hemiplegia on an endoscopic exam. Ultrasound can be valuable to differentiate between the two conditions. The aforementioned hyperechoic CALM muscle is seen with hemiplegia, whereas abnormal shape and orientation of the thyroid, cricoids, and arytenoid cartilages are seen with dysplasia. The thyroid lamina is elongated dorsally, extending dorsal to the muscular process of the arytenoid cartilage. The cricothyroid articulation is also not visualized with laryngeal dysplasia. Instead, a gap is seen between the caudal margin of the thyroid and the rostral margin of the cricoid cartilages.

7. Pulmonary Disease and Poor Performance

Lung disease can compromise ventilation as profoundly as URT obstruction. In addition to poor performance, symptoms of pulmonary disease include coughing, decreased effort when working, increased respiratory effort during exercise, and prolonged recovery after exercise. Coughing as a symptom is not specific to pulmonary disease and is not observed in all cases of pulmonary disease. Abnormal respiratory noise during exercise is not normally seen with pulmonary disease. Inflammatory airway disease (IAD) and EIPH are the most common noninfectious lung conditions that compromise performance in equine athletes.

Inflammatory Airway Disease

IAD, also called small airway inflammatory disease, is a common, chronic condition that has a documented negative effect on performance. Inhaled particles (dust and molds) are important in the development of airway hyperreactivity. Younger horses that are housed in stalls are at greatest risk for IAD. The most common complaints are chronic cough, decreased performance, and prolonged recovery after work. Nasal discharge is not usually noted. Endoscopic examination will reveal an accumulation of mucus in the trachea. Larger volumes of mucus in the trachea have been associated with a greater negative effect on performance. Tracheal mucus found at postexercise endoscopy is more meaningful than the same finding if the patient has just been transported. Mucus will often accumulate in the trachea of a normal horse, and it is not able to lower its head while standing in a trailer for long periods. Bronchoalveolar lavage (BAL) is the best test to confirm a suspected case of IAD. Cytology is performed on the fluid obtained. With IAD, the ratio of inflammatory cells (primarily neutrophils) to macrophages is increased. IAD can be confused with bacterial or viral bronchopneumonia, but fever, lethargy, or diminished appetite is not expected with IAD, unless concurrent infection exists. Complete blood count, serum amyloid A measurement, thoracic ultrasound, and tracheal aspirate for cytology and culture are useful tests to rule out bacterial infection. Pathogenic bacteria, most notably Streptococcus spp., can be commonly isolated from transtracheal aspirates of horses with IAD. Whether bacterial infection plays an inciting role in IAD or pathogens colonize the airways secondarily to impaired mucociliary clearance is unclear. Antibiotic therapy can improve symptoms, but relapse is common if additional measures are not taken to manage the inflammatory disease. Environmental management is the most important treatment for IAD (i.e., decreasing exposure to dust and molds). Bedding of shavings is preferred over straw. Hay must be good quality. Soaking or...
Exercise-Induced Pulmonary Hemorrhage

EIPH is a common disorder of equine athletes that perform at high levels of exertion. Poor performance or epistaxis is the most common presenting complaint with EIPH. Most horses that perform at high speed incur some degree of EIPH, but epistaxis is rare (0.1 to 9%, depending on the study). The source of bleeding in EIPH is from capillary wall rupture in the caudodorsal lungs during exertion. Pulmonary capillary walls are thin by necessity to allow rapid gas diffusion. Pulmonary arterial pressure rises to about 100 mmHg at maximal exercise. The cause of capillary failure in the lung with EIPH is thought to be excessive transmural pressure. During strenuous exercise, the alveolar pressure swings rapidly from negative during inspiration to positive during expiration. Increased airway resistance from URT obstruction or lower airway disease causes even larger pressure swings and greater stress on the thin capillary walls. The standard diagnostic test for EIPH is endoscopy of the trachea postexercise. The optimal timing for examination is around 1 to 2 hours after exercise to best grade the severity of the episode. Blood in the distal trachea will be visible for 1 to 3 days, depending on the individual and the amount of hemorrhage. Examination of tracheal wash or BAL samples for red blood cells or phagocytized hemosiderin is more sensitive than endoscopy and will remain positive for at least 7 days posthemorrhage. Despite a multitude of studies on various breeds and uses, a negative effect of EIPH on performance has only been found in the Thoroughbred racehorse. Studies in other breeds and uses have not been able to correlate EIPH with decreased performance. Given the frequency of occurrence and ease of diagnosis of EIPH, it is likely overdiagnosed as the cause for poor performance if the actual cause remains obscure. An abnormal noise coincides with EIPH and poor performance, dynamic endoscopy should be considered if there is no URT condition at rest. With complaints of poor performance, EIPH, and occasional coughing, BAL should be considered to rule out IAD. No studies have correlated URT obstruction or IAD to increased incidence of EIPH. It is likely that obstructive airway conditions would increase transmural pressure on the capillary walls during exertion. Anecdotally, when horses with an obstructive URT condition or IAD also have a history of EIPH, the EIPH will often lessen or cease if treatment for the primary condition is successful. The only medication that has been shown to have a benefit in reducing EIPH is furosemide. Furosemide has also been shown to improve racing performance in Thoroughbreds. The mechanism(s) of action for reduction of EIPH or improvement in performance with furosemide administration remain uncertain.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Poor Performance Workup in the Eventing or English Sport Horse

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The ability to determine the cause of poor performance in the 3-day eventing or English sport horse is greatly enhanced by a consistent methodical approach to the examination and extensive knowledge of the discipline involved. Additionally, an open mind, good communication with the rider or owner, and collaborating with other experts can improve the success rate of correct diagnosis. Author’s address: Andre Buthe Equine Clinic, Marlborough, United Kingdom; e-mail: christianaober@gmail.com. © 2018 AAEP.

1. Introduction

Although there are multiple publications on causes of poor performance in the racehorse,1–4 and endurance horse,5 there is a deficit of studies quantifying discipline specific causes of poor performance in the sport horse. This is likely due to challenges with accumulation of adequate numbers within each discipline and the number of variables affecting a poor performance workup. The author would also suggest that the prevalence of certain causes can vary within each discipline. This paper will focus on the poor performance workup in the 3-day eventing and English sport horse.

Poor performance can be defined as either 1) a recent deterioration in performance in a horse that was performing up to expectations, or 2) inability to reach a desired or expected level of performance in an unproven horse. The latter scenario can sometimes be more challenging for the veterinarian to assess given the greater potential for extrinsic variables such as lack of talent or potential in the horse or management factors in the program.

Poor performance is often multifactorial, which only complicates pinpointing the culprit.

As sport horse practitioners, the prevalence of certain causes guides our methodical approach. Discipline, clientele, area of expertise, and even geographical location will affect prevalence. A template or work flow for a successful poor performance workup (Fig. 1) will be an ever-evolving and unique path for each practitioner guided by the previously mentioned factors.

2. Fundamentals of the Poor Performance Examination in the Eventer or English Sport Horse

1. Thorough history
2. Careful palpation and observation (pre and post exercise)
3. Auscultation of heart and lungs (pre and post exercise)
4. Moving examination
5. More extensive under tack or in work examination (crucial component of exam)
6. Laboratory tests
7. Additional diagnostics (local or perineural blocks, imaging, etc.)
8. Multiple evaluations sometimes on different days in varying environments

A thorough history is paramount to the start of the poor performance examination. This should begin with a clear understanding of why the veterinarian was asked to examine the horse, making certain to clearly hear and understand the owner and or trainer’s specific complaint. Why was the veterinarian called in and what is the specific complaint? The veterinarian should know whether the horse was able to perform at the desired level and can now no longer achieve that level, or was it because the horse is showing diminished performance and was able to perform at the desired level previously? Was it because this is a younger prospect that has never been able to reach expectations? Does the horse appear to have recent onset exercise intolerance or evidence of a recent injury or episode of disease? Finally, is the owner or rider keenly aware of the horse and its expected level of performance or should another person, e.g., the trainer or groom be consulted to give feedback? This history can start to help the veterinarian formulate a plan and work flow toward defining the cause of the poor performance.

Valuable information can be gained from palpation and observation of the horse in its stall or natural environment prior to exercise. While getting a thorough history, observe the horse in its environment. Comparison of symmetry, palpation of soft-tissue structures and the axial skeleton pre- and post-exercise can be helpful. The author prefers to have a baseline hands-on examination of the horse in its stall prior to any exercise. The valuable information provided by the head groom in a professional yard cannot be underestimated. The person that spends every day looking after the horse often notices subtle changes such as swellings, effusion, or change in muscling than can be of help in the workup.

In the author’s opinion, the overwhelmingly most common contributor to poor performance in the English sport horse is musculoskeletal pathology (Fig. 2). Therefore, the moving examination and the under-tack examination are critical components. This portion of the examination involves a thorough orthopedic examination including evaluation at walk and trot, flexion tests, lunge on hard and soft surface, as well as an under-tack examination. A cursory neurologic examination is generally performed at this time as well and since separation of lameness from ataxia can be difficult it is important to record the findings of this examination. If there appears to be a primary musculoskeletal or lameness issue, even if they weren’t suspected by the rider, then it is beneficial to further evaluate these problems before proceed-
3. Maximizing the “In-Work/Under-Tack” Examination

The under-tack examination is a crucial portion of the poor performance examination. The horse must be seen doing the job it is expected to do, ideally with the usual rider in their tack and on an appropriate surface. If the horse is a driving horse, it may need to be seen in carriage. This often necessitates prior communication to make sure an appropriate surface and rider are available for the examination. Some things that should be included as part of a holistic evaluation or poor performance are saddle fit assessment, watching the horse being tacked up, walking out of the barn, being mounted, and watching the warmup as these can all give insight. Sometimes the in work examination may include observing two different riders, letting the horse stand after some work and then picking back up again, and watching the rider post on the opposite diagonal. Additionally, factors such as saddle slip and recovery post exercise can also be evaluated. It may sometimes involve a gallop or conditioning session in the case of a 3-day event horse. If there is question with regard to the level of low-grade orthopedic pain, then perhaps a short course of NSAIDs followed by re-evaluation under tack will be beneficial for treatment of one recognized or known source of pain and then a re-evaluation is indicated.

4. Prevalence of Causes

In a retrospective assessment of the last 200 cases in the practice evaluated for poor performance, 77%, the overwhelming majority, had a primary musculoskeletal cause, 18% had a primary internal medicine diagnosis, and 5% had other extrinsic causes as the source of poor performance. The author and practice collaborators have a caseload in the United Kingdom of approximately 70% 3-day event horses, 25% show jumpers, and 5% other English sport horses. Additionally, the practice is specialized for predominantly orthopedic, sports medicine work, and management of the equine athlete, which certainly affects case distribution.

Regardless of practitioner variation, the dominant cause of poor performance in this population of horses can be expected to be musculoskeletal pain. Further defining musculoskeletal pain would include (listed in order of prevalence) 1) lameness, 2) subclinical orthopedic pain, 3) axial skeletal pain, 4) muscular issues (muscular injury and metabolic muscle disease), and 5) overtraining syndrome. It should be noted there could be a combination of the above.

A less-common diagnosis for this population of poorly performing horses would include the internal medicine causes to include: 1) respiratory causes (upper and lower airway), 2) gastrointestinal causes (including gastric ulcers), 3) neurologic causes (including infectious diseases such as equine protozoal myeloencephalitis (EPM) or degenerative such a CVM), 4) cardiovascular causes including arrhythmias and significant murmurs, and 5) systemic illness (more acute history).

Finally, an even smaller but very challenging group to diagnose and approach would include the extrinsic causes which may include 1) lack of talent or genetic capacity of the horse, 2) bad riding, and 3) management issues.

Any combination of the above three groups is also a possibility that can lead to a very time-intensive and exhaustive examination. It also goes without saying that the identification of an abnormality doesn’t have a linear relationship to poor performance. For example, identification of a heart murmur in an upper-level event horse is unlikely to be a contributing factor to the poor performance (although it should not be completely ignored).

5. Discipline Specificity

Some of the more prevalent and discipline specific causes of poor performance in the three-day-event horse versus other English sport horses relate to the repetitive conditioning and galloping necessary for fitness at the upper levels. A Concours Complet International **** horse (CCI***** could be required to cover up to 6,270 meters over 11 minutes at a...
speed of 570 meters per minute with up to 40 jumping efforts on cross country. Therefore, one will see injuries relating to repetitive stress and strain on uneven ground and varied footing. This can lead to many clinical or subclinical orthopedic problems. Subchondral bone disease, caudal heel pain, superficial digital flexor tendonitis, suspensory desmopathy, and back pain are very common causes that the author identifies for poor performance in this population. Additionally, rider tendencies toward excessive fitness work, especially in the inexperienced riders, can lead to over-training syndromes and a higher incidence of concussive stress-related injuries. The capacity for the genetic ability of the horse to be able to gallop 10 to 11 minutes can be difficult to quantify when a rider complains of poor performance during the cross-country test or early onset of fatigue. During the endurance test of cross country, unique to the sport of 3-day eventing, muscle abnormalities and any upper or lower airway restrictions can lead to a horse that is unable to gallop the distance without excessive fatigue due to physiologic limitations.

6. Overtraining
This syndrome is well described in human athletes as a cause of poor performance and although it is more difficult to define in the equine athlete, it should not be overlooked.8,14 “In humans, overtraining syndrome has been defined as an imbalance between training and recovery manifesting as a syndrome of chronic fatigue and poor performance that may be accompanied by physiological and psychological changes. A similar syndrome has been described in horses using both cross-sectional observations and longitudinal studies with progressively increasing training loads until signs of overtraining were observed. Once other causes of poor performance have been ruled out (by an extensive examination previously detailed), overtraining syndrome should be suspected in horses with evidence of sustained decreased performance in association with one or more physiological or psychological signs.”8,14 Obviously the key here is being able to rule out other causes and diagnose a dynamic condition. However, just because it can be a difficult diagnosis of exclusion does not mean it shouldn’t be on our list of possibilities. Suggested physiologic signs that have been linked to overtraining would include neuroendocrine alterations, increases in muscle enzymes and gamma glutamyl transferase (GGT), loss of body weight, alterations in heart rate, and lactate responses to exercise. “Behavioral signs were both consistent and an early marker of overtraining syndrome in studies in horses, and more research on developing behavioral scores to assist in early detection of over-training syndrome in horses as have been achieved for humans is warranted.”8,14 This is probably an easier diagnosis in a professional program where the same groom is with the horse daily and can give feedback on behavioral changes. Some of these riders may utilize heart rate monitors during conditioning work and may notice an abnormal trend with either resting or pre-exercise heart rate or elevation of heart rate on routine gallop. Evaluation of horses in specific training yards can also highlight the benefit of examining blood chemistry profiles during the pre-season period to have a basis for comparison during peak season. The author would also suggest that it likely would not be an isolated incident or case and some barns or training facilities may be more prone to these cases than others.

7. Value of Pre- and Post-Season Baseline Examinations
Having a more complete or extensive medical baseline on an upper level performance horse can lead to streamlining the poor performance examination. It can help to eliminate variables. A CCI*** or CCI**** event horse under the author’s management would typically get a baseline preseason examination (January or February). This exam would include a discussion with the rider with regard to performance and schedule, auscultation of heart and lungs, palpation, an orthopedic examination, and potentially baseline diagnostics (ultrasound of previous injury or baseline radiographs of maintenance issue to assess progression). These results and the previous history of the horse is used to develop a proposed management plan for the season ahead, always subject to change. This visit may include additional members of the horse health yard team such as the farrier or physiotherapist. These horses will often also get a post-season examination 3–4 weeks post-CCI, which may include a moving examination and baseline ultrasounds at least of forelimb tendons and suspensory ligaments. This protocol would be guided by the high prevalence of soft-tissue injuries in the 3-day event horse and the desire to use the off season for identification and rehabilitation of minor injuries that could become more problematic in the next season. Having several years of pre- and post-season examinations on these upper level horses allows earlier detections of changes and may help to more quickly identify legitimate causes of poor performance during the season.

8. Summary
In summary, a poor performance workup of the English sport horse can be a time-consuming and comprehensive examination. The likelihood of a successful diagnosis and outcome can be greatly enhanced by a methodical approach by the practitioner and extensive knowledge of the specific discipline. Musculoskeletal causes are the overwhelming majority of cases in this population. Although challenging, these cases can be exceptionally rewarding for both the client and the practitioner.
HOW TO DIAGNOSE POOR PERFORMANCE IN THE EQUINE ATHLETE

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.

References
1. Introduction

Poor performance is the inability of an individual to perform at a level that can be reasonably expected based on the individual’s physical characteristics, level of training, and/or previous performance. Maximal performance involves the coordinated, optimal functioning of almost all body systems and requires that these systems operate at or close to their maximum capacity. Any decrease may be critical to the equine athlete. When evaluating the cause for poor performance in horses, the conditions most often identified are abnormalities of the respiratory and musculoskeletal body systems.1–5 Moreover, a large portion of horses evaluated for poor performance has been found to have multiple concomitant disorders.2,4,5

Neurologic disease can lead to gait deficits that might be confused with lameness, and discerning between the two can be difficult, especially when signs are subtle. However, identifying the nature of any perceived gait abnormalities, be it neurologic, distal limb, or axial skeleton, it is important to determine prognosis and further treatment. There are many types of disorders of the neurologic system that can lead to subtle gait abnormalities as a result of ataxia, dysmetria, and/or weakness (paresis). A thorough physical examination and gait evaluation, including lameness and neurologic examinations, are needed to identify which body system is most likely responsible for the deficits. Here, the author will provide some key elements to a diagnostic approach for a horse with poor performance in which neurologic disease is suspected.

2. Materials and Methods

Neurologic Examination

The goals of the neurologic examination are to 1) determine whether disease of the neurologic system exists, 2) to localize the lesion to a particular area of the nervous system, and 3) to describe and record the responses as a baseline for future evaluations. There are many good sources that describe how to complete a neurologic examination in the horse.6,7 Here is a brief overview of some of the critical components of a neurologic examination. First one needs to know the signalment of the horse since it is well known that there are risk factors for certain diseases based on breed, gender, and age of the animal (e.g., cervical vertebral compressive myelopathy, cerebellar abiotrophy, equine motor neuron disease, equine protozoal myeloencephalitis). The history of the disease is important to learn, in particular when the onset of clinical signs occurred and whether the disease is static, progressive, or recur-
rent. Some conditions may be present since birth and are progressive, whereas others may be associated with a move from one location to another, or may be secondary to trauma. A good physical examination will allow the examiner to find unusual and or unexpected abnormalities such as tachycardia or an elevated temperature. Additionally, a good physical examination may point out lesions associated with an abnormal gait or areas of asymmetry (head, muscles).

The neurologic examination starts with an evaluation of the horse’s behavior and mentation, preferably in an area the horse is comfortable in (stall, paddock). Abnormal mentation includes depression, obtundation, and coma. Abnormal behaviors that may be discovered include seizure activity, epilepsy, head pressing, circling, cortical blindness, narcolepsy, or headshaking. At this time, the horse’s stance and posture can also be evaluated. Once the horse is in a safe area for further evaluation, one can walk around the horse to look at other aspects of stance and posture, look for the presence of proprioceptive deficits and/or muscle fasciculations, and determine symmetry of muscle development. The author prefers to start the remainder of the neurologic examination by working from head to tail and starts with evaluation of cranial nerve function before evaluation of sensation and finally gait. Reflexes can be evaluated in foals or recumbent horses.

Careful assessment of cranial nerve function is important since there are a number of diseases that may result in dysfunction of those nerves in addition to abnormalities found elsewhere. This can be found in particular with diseases such as polyneuritis equi and equine protozoal myeloencephalitis (EPM). Furthermore, if there are deficits noticed in multiple cranial nerves, there may be central disease, for example in the area around the brainstem since that is where most cranial nerves originate. Deficits of the afferent pathways (sensory) would include reduced smell, taste, vision, hearing, or balance and specific proprioception. Deficits of the efferent pathways (motor) would include reduced ability to change pupil diameter, lesions of eyeball movement, reduced muscle of mastication mass, altered facial expression, reduced ear play, problems with swallowing, vocalization, and reduced tongue movement or tone. The most commonly seen deficits of cranial nerves in the horse include facial nerve paralysis, head tilt, laryngeal dysfunction, and dysphagia.

Next, the author will test sensation and evaluate the horse’s range of motion of the neck and back. Evaluation of the gait in horses suspected to have neurologic disease aims at specifically identifying the presence of ataxia, paresis, dysmetria, and spasticity. Ataxia is considered a lack of coordination of muscle movements and in the horse typically arises from lesions of the vestibular system, cerebellum, or deficits of the ascending sensory systems. Paresis, or weakness typically originates from a lesion in the upper motor or lower motor neuron tracts, or can be secondary to muscle disease or weakness. Dysmetria is frequently associated with ataxia and the term is used to describe whether there is excessive (hypermetria) or reduced (hypometria) movement of joints. Hypermetria can be seen with spinocerebellar disease and hypometria typically is seen as stiffness or a tin soldier gait. Although dysmetria and spasticity are difficult to differentiate clinically, spasticity results from reduced inhibition of extensor motor neurons. In the horse, sensory ataxia seems to be predominately associated with spinal cord disease in which proprioceptive input to the cerebellum is compromised. Evaluation for the presence of ataxia, paresis, and dysmetria happens while watching the horse at the walk in a straight line followed by watching how the horse handles numerous challenges such as walking with the head elevated, backing, circling, walking in a figure-8, walking over curbs, performing a tail pull, and walking down a hill. A subset of abnormalities that can be identified suggesting ataxia, paresis, or dysmetria are shown in Table 1.

In equine neurology, scoring of ataxia is necessary for diagnostic and prognostic purposes and for determination of efficacy of therapeutic regimens. Currently the severity of ataxia assessed during a neurologic examination is graded using a modified ordinal grading scale (modified Mayhew scale; Table 2) where grade 0 is assigned to horses without

<table>
<thead>
<tr>
<th>Ataxia</th>
<th>Paresis</th>
<th>Dysmetria</th>
</tr>
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<tbody>
<tr>
<td>Limbs placed in abnormal position</td>
<td>Toe dragging</td>
<td>Limb stiffness, little movement of joints (hypometria)</td>
</tr>
<tr>
<td>Limbs placed in an irregular pattern, distance, or timing</td>
<td>Interference</td>
<td>“Tin soldier gait”</td>
</tr>
<tr>
<td>Truncal sway</td>
<td>Knuckling</td>
<td>Excessive movement of joints (hypermetria)</td>
</tr>
<tr>
<td>Stepping on itself</td>
<td>Losing balance, falling down</td>
<td></td>
</tr>
<tr>
<td>Circumduction</td>
<td>Pivoting</td>
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Note that some of these can overlap, for example, pivoting and knuckling can be seen with ataxia, but can also be considered a sign of weakness.
rologic deficits and grade 4 is assigned to horses that stumble, trip, and fall spontaneously. Grade 5 is reserved for horses that are recumbent.

The neurologic examination is usually completed with the horse at a walk; however, the author will have most horses trot out and back at least once to determine whether any other gait deficits become apparent at this gait. Most horses with spinal ataxia, grades 1 to 3, will be able to do this. A more comprehensive lameness evaluation is needed in horses that have obvious lameness in conjunction with neurologic disease, and in horses that have subtle gait deficits with components that can be produced by disorders affecting the neurologic system and/or the musculoskeletal disease, such as paresis.

Ancillary Diagnostics

Diagnoses that will improve our understanding of the horse's neurologic system include imaging of the neck through cervical radiographs and cervical articular process ultrasonography, and cerebrospinal fluid analysis. More complex diagnostic tools that can be valuable to study the cervical spinal cord include myelography and computed tomography (CT) myelography. The neuromuscular system can be further studied using muscle and/or nerve biopsies and through clinical neurophysiological studies. In particular, electromyography and nerve conduction studies can be useful to evaluate lesions of the lower motor neuron or motor unit.

In most areas of North America, EPM should be one of the main differential diagnoses for horses identified with disease of the central nervous system. Unfortunately, definitive diagnosis of this disease requires postmortem confirmation of protozoal infection of the central nervous system. Numerous studies have evaluated laboratory tests for the antemortem diagnosis of EPM, and most recent research has focused on the surface antigen ELISAs, which are quantitative (end-point titer) tests based on *Sarcocystis neurona* surface antigens. For highest accuracy in antemortem diagnosis of EPM, the American College of Veterinary Internal Medicine has recommended the following steps that are outlined in the most recent consensus statement on this topic. First, the presence of clinical signs consistent with EPM should be confirmed by conducting a thorough neurologic examination. Second, other potential causes should be ruled out using available tools (e.g., cervical radiography). Third, immunodiagnostic testing of serum and cerebrospinal fluid should be conducted to confirm intrathecal antibody production against *Sarcocystis neurona* or *Neospora hughesi*. The ratio of antibody in serum to cerebrospinal fluid (CSF) will reveal intrathecal antibodies in most cases of EPM. The SnSAG2, 4/3 ELISA serum:CSF titer ratio and NhSAG1 ELISA serum:CSF titer ratio are the only tests currently offered commercially that provide information regarding intrathecal antibody production based on serum and CSF titers.

### 3. Results

Undoubtedly the two most common neurologic disorders that can impair a horse's gait and lead to poor performance in the United States are cervical vertebral compressive myelopathy and equine protozoal myeloencephalitis. Both of these conditions can affect the horse in a significant enough fashion such that there is obvious neurologic disease and when appropriate testing algorithms are followed the diagnosis is made. However, both of these conditions can also lead to subtle disease accompanied by subtle gait deficits. Additionally, neck lesions can be a cause for thoracic limb lameness when pain cannot be localized to the limb. It is unclear what aspects of the neck are painful in those situations. There are no reports in the literature of nerve root impingement causing radicular or referred pain in the horse. However, there is a report in which traditional myelography was compared with post-mortem contrast enhanced computed tomography in 6 horses that demonstrated the presence of nerve root compression by a malformed articular facet, at the level of the proximal intervertebral foramen in 2 horses. This seems to be a condition that is recognized clinically with increasing frequency and we expect that with advanced imaging and use of electrodiagnostics some of these syndromes can be diagnosed and better explained in the near future. Other nervous system disorders associated with poor performance include peripheral neuropathies, space-occupying lesions, and infectious/inflammatory diseases such as neuroborreliosis.
4. Discussion

Athletic horses that are evaluated for poor performance can be complex cases requiring a multifaceted approach to the diagnosis, especially to determine the types of structures involved and the severity of injuries. A surprising number of horses presenting for poor performance are found to have gait deficits, even when the owner or trainer has not reported these.2–5 This highlights the fact that many of these conditions are subtle and require diagnostic expertise and/or the use of sophisticated equipment to be identified. Furthermore, one study showed that 74% of horses with musculoskeletal abnormalities had disturbances involving two or more anatomical locations and 47% involved three or more anatomical locations.5 Their data suggest that inadequate performance in the elite athlete in many cases may be due to the additive effect of musculoskeletal injuries, which causes enough discomfort to result in limiting performance. It has also been shown that induced thoracic and pelvic limb lameness affects thoracolumbar kinematics,16,17 which over time can result in axial skeleton pain and/or dysfunction. One can imagine that these are challenging cases to diagnose and find effective methods of treatment for. Frequently, through a careful and systematic approach, that includes utilizing expertise in the fields of lameness and neurology, the cause of the limitation can be discovered.

Acknowledgments

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

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The Author has no conflicts of interest.

References
How to Workup Poor Performance in the Western Horse

William S. Rhoads, DVM

1. Introduction
Poor performance in the western performance horse, as in all equine sports disciplines, has a huge economic impact. The western performance horse is comprised of a large variety of age groups and disciplines including the western show horse, reining, cutting, barrel racing, roping, and others. Generally speaking, the futurity and aged event horses compete from the ages of 2 to 6 years, depending on discipline. Additionally there is a tremendous market of “weekend” horses that participate in competitions at older ages and at all levels. Some of these western disciplines are timed events (roping, barrel racing), whereas others are judged.

2. Materials and Methods
Clinical or subclinical soreness or lameness account for approximately 90% of performance-related issues in the western performance horses in the author’s practice. As some of these horses are not required to jog or trot in their respective disciplines (reining, cutting, roping), many times lameness is not the presenting complaint. Oftentimes what is observed by the rider or trainer is a perceived decrease in the ability to perform a certain maneuver that is required for their specific discipline.

In the author’s practice, the initial performance examination is no different than the pre-purchase or lameness exam. The horse is evaluated at a walk and jog on a lunge line in a sand arena traveling in both directions of the circle. Flexion tests are performed systematically on both front and back legs. The author generally performs a distal limb and carpal flexion in the forelimb, and a distal limb, hock (spavin), and upper limb flexion on the hind limb. Thorough palpation of all structures is conducted, as this is a very critical part of finding primary and secondary problems, and palpations are compared from side to side. The horse is then evaluated in hand at a walk and trot on a concrete surface. In some instances, the horse may then be evaluated under saddle. Many times a problem is not apparent until the horse is actually performing that specific maneuver.

In cases where clinical evidence of lameness is present, the author will proceed with either diagnostic anesthesia or diagnostic imaging if an obvious palpable abnormality is present. Oftentimes there are multiple sources of soreness, so it is best to prioritize what is most clinically relevant at the time. Recheck examinations are often necessary and very helpful after instituting a treatment plan not only to determine the efficacy of the treatment,
appropriately as cervical particular vulnerable to equine protozoal myelitis, so practice, the young, highly stressed athlete is particularly is suspected, a thorough neurologic diagnostic workup is performed. In the author's area of component is suspected, a thorough neurologic diagnosis is performed. As cervical spinal compression due to cervical vertebral malformation or cervical facet osteoarthritis also can occur in this demographic of animals, a standing cervical radiographic and/or myelographic examination should be considered.

Myopathies are also common in the western performance horses, and can cause significant loss of performance. In these cases, the initial workup includes analysis of muscle enzymes, and in some cases performing pre- and post-exercise analysis. As there are genetically identified causes of muscle disorders in the breeds of horses used in the western discipline (polysaccharide storage myopathy [PSSM] type 1 and 2), muscle biopsy and genetic testing of hair or blood should be considered.

Disorders of the respiratory system may cause the same types of performance limitations in the western horses that exhibit at speed (barrel horses) that they do in the racing Thoroughbred. Upper respiratory functional abnormalities, epistaxis, and allergic airway disease are very common, particularly in the rodeo horse and horses that compete at speed. The typical diagnostics include resting and dynamic upper airway endoscopy, as well as trans-tracheal lavage or bronchoalveolar lavage analysis.

Less commonly, cardiac disease or other systemic ailments (renal or hepatic disease) can cause poor performance in the western horse. When suspected, the diagnostic examination may include laboratory testing, electrocardiogram, and echocardiogram.

3. Discussion
Poor performance is a common and economically relevant issue in the western performance horse. Each discipline has conditions that are notorious for causing limitations in performance. Most of these are due to soreness or lameness, although gastric ulceration, muscle diseases, neurologic dysfunction, respiratory or cardiac abnormalities should not be overlooked. Every attempt should be made to find the underlying cause or causes of the poor performance, and this may take several examinations and multiple diagnostic modalities. In some instances a response to treatment based on knowledge of the most common clinical abnormalities and a clinical “hunch” may lead to a proper diagnosis.

Acknowledgments
Declaration of Ethics
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The Author has no conflicts of interest.
How to Diagnose Poor Performance in the Thoroughbred Racehorse

Ryan Carpenter, DVM, MS, DACVS

1. Introduction
In a sport where races are won and lost by fractions of a second, subtle problems can have a significant impact on performance. Poor performance is a relatively subjective complaint, especially in the Thoroughbred racehorse. Poor performance refers to horses that may train at a decreased level or are unable to reach an expected level based on their physical characteristics, genetic potential, and training status. With an experienced racehorse, performance can often be defined by its racing form. Objective criteria such as race classification, finishing position, earnings, or speed figures can be influenced by a multitude of factors. However, with young horses that have a limited past performance or history, a clear understanding of the horse’s true ability can be difficult. Regardless, identifying the specific cause that results in a decrease in performance can be a diagnostic challenge. Therefore, it is important to clearly understand the trainer’s primary concern or complaint in order to formulate an effective plan to reach a diagnosis for the underlying cause of poor performance.

2. Materials and Methods

History
When dealing with poor performance, a complete and thorough history is critical in understanding potential contributors to the issue as well as to identify the trainer’s primary concern. Often this information will help direct your initial steps. However, since there are so many variables it may become a process of elimination when no clear path is identified. Eliminating what is not the problem allows us to pursue the path of what is the cause. It is important to understand all the potential causes of poor performance so each can be investigated in order to reach the proper diagnosis.

Physical Examination
While the basic physical examination is often straightforward, it must be thorough and complete. Auscultation of the thoracic cavity should include a rebreathing examination. When auscultating the heart, pay close attention to heart rate, rhythm, and the presence of a cardiac murmur. It is important to listen to both sides of the chest and deep behind the elbow on the left side. Additionally, hematological and serum chemistry analysis and resting endoscopic examination is a good starting point to gain vital information.

Lameness Examination
As with any sport, occupational-related injuries from racing and training are prevalent. Ideally,
Exertional rhabdomyolysis (ER), or commonly referred to as “tying up,” is a common problem that results in a transient lameness following exercise and often resolves within a few hours. Obvious cases present with muscle cramps and as a hot, sweaty horse following exercise are not difficult to diagnose. However, more subtle cases can be difficult to diagnose based on clinical presentation but will demonstrate elevated serum levels of CPK and AST. These cases are typically seen in young fillies and respond well to acepromazine (5–10 mg IV) and/or dantrolene (250–500 mg PO) prior to exercise and an alteration in training program and diet.
Cardiovascular Examination
The presence of a heart murmur is unlikely to have a negative association with performance. It is not uncommon for a systolic murmur to be appreciated at rest but not evident following exercise. Several horses with very significant murmurs of grade III or IV can compete at the highest stakes level with no apparent impact on performance. Second-degree atrioventricular (AV) blocks are commonly ausculted at rest and typically are not following exercise and have no association with poor performance. While atrial fibrillation is associated with poor performance, this is an extremely rare diagnosis and treatable.

Gastric Ulcers
The prevalence of gastric ulcers in Thoroughbred racehorses is as high as 90% to 100%. It can be difficult to examine a horse clinically and make an estimate of the corresponding endoscopic gastric ulcer grade. Some horses that present like they would have bad ulcers with a poor hair coat and mild colic episodes following NSAID treatment or following a grain meal, have normal gastroscopies while other horses that present clinically normal have severe grade 4 ulceration. Therefore gastroscopy is critical in achieving an accurate diagnosis. In recent years, trainers have taken the approach of treating all horses in the barn with a maintenance dose of omeprazole (1 mg/kg). While this is sufficient for most horses, some will require a higher dose. Additionally, several alternative products frequently become available and are presented as cheaper alternatives. While this is very appealing to most trainers, these products are often inferior. It is not uncommon to identify clinically significant gastric ulcers present in horses that have recently changed from omeprazole to an alternative product.

Neurologic Examination
In the author’s experience, the two most common neurologic conditions that are associated with poor performance are osteoarthritis of the cervical vertebral facet joints and equine protozoal myeloencephalitis (EPM). While cervical cord compression or “wobblers” should be considered, these cases are often identified prior to arriving at the racetrack and therefore less likely to be associated with poor performance once the horse is actively training at the racetrack.

Osteoarthritis of the cervical vertebral facet joints is a common cause of hind-limb lameness and poor performance. These horses demonstrate a stiff neck or altered gait relative to changes in head and neck position. A hind-limb lameness or a shifting front-limb lameness is seen in some cases. Diagnosis is typically confirmed with nuclear scintigraphy demonstrating an increase in radiopharmaceutical uptake in the C4–C5, C5–C6, and/or C6–C7 region without any uptake in the hind end. The treatment of choice is ultrasound-guided injection of the articular facet with corticosteroids and a chondroprotective agent. The response to treatment is often very good and rapid.

EPM is known as the disease that has no “classic” characteristic clinical signs. EPM is most prevalent in young horses that originated from an endemic area and the stress of shipping and/or onset of intense training causes enough stress on the individual where clinical signs become apparent. However, this disease can also present in older horses that have been at the racetrack for years. These horses present with an ill-defined lameness, failure to train, and/or poor performance. Musculoskeletal evaluation does not reveal any areas of concern and other diagnostics are unremarkable. The immunofluorescent antibody, western blot, and Surface AntiGens blood test is a quick useful way to identify these cases. It is important to keep in mind the complexity of diagnosing this disease; therefore, a cerebrospinal fluid (CSF) sample may become necessary, and is the gold standard for diagnosis. They typically respond well to treatment and are able to maintain active training once the initial improvement is noted which is often within the first week.

3. Discussion
Although the presenting complaint of poor performance can be relatively subjective and a diagnostic challenge, understanding the underlying pathogenesis of common causes that relate to poor performance in the Thoroughbred racehorse will allow the practitioner to formulate a logical plan. This will allow the practitioner to compile the necessary information so a diagnosis can be achieved. In the author's experience, conditions that are diagnosed with a dynamic, over the ground, exercise endoscopy, elevated GGT, EPM, and subtle lameness issues are more commonly causes of poor performance in the Thoroughbred racehorse. Whereas lower respiratory disease such as EIPH or chronic low-grade mucus, ER, gastric ulceration, and osteoarthritis of the cervical vertebral facet joints occur less commonly. Cardiovascular contributors of poor performance (PP) appear to be relatively uncommon causes of poor performance.

The Thoroughbred racehorse is an individual and not a machine. Therefore factors such as surface, training style, rider, time of day training, and environment need to be considered. It is not uncommon for a horse to reach its full potential once a change has been made. This aspect makes reaching a diagnosis in all cases difficult. To complicate the issue, one must not forget that a common cause of poor performance is lack of ability and unrealistic owner expectations. Every 2-year-old is purchased to be the next Kentucky derby winner. Unfortunately, only 20 will reach the starting gate and 1 will cross the wire first. Some owners and trainers have the ability to come to terms with this better than others. However, if a disease is the underlying cause, we can maximize our results and respond to treatment
when an accurate diagnosis is achieved. Therefore, it is important to pay attention to the subtleties with these athletes as it translates to significant differences on the track. There is no greater accomplishment than helping our athletes reach their full potential.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnote


*GastroGard, Merial Ltd., Duluth, GA 30096.
How to Determine if Muscle Disease is Contributing to Poor Performance

Stephanie J. Valberg, DVM, PhD, DACVIM, DACVSMR

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1. Introduction
Optimal function of skeletal muscle is essential for successful athletic performance. Even minor derangements in locomotor muscle function will impact power output, coordination, stamina, and desire to work during exercise. Although many myopathies are easy to recognize in the acute stages, low grade muscle strains or weakness and chronic myopathies may be difficult to diagnose. The challenge in identifying their contribution to poor performance includes the following:

1. Locating and assigning significance to focal muscle strain.
2. Differentiating between uncooperative behavior with exercise and exertional pain emanating from the musculature.
3. Determining the degree to which orthopedic pain contributes to muscle pain.
4. Determining the degree to which myopathies contribute to lameness/pain.
5. Determining the contribution of muscle weakness to gait alterations.
6. Differentiating myogenic from neurogenic weakness.

2. Diagnostic Approach
The diagnostic approach to poor performance involves, by necessity, a detailed evaluation of all body systems. Frequently, poor performance in athletes is due to a combination of orthopedic and muscle pain, and a systematic evaluation of both systems provides the most satisfactory outcome for the client and the horse. Key components of determining the source of pain or altered gait are a thorough history, physical examination, neurologic and lameness examinations, and selection of appropriate ancillary diagnostic tests.

History
The history should include performance level, fitness level, exercise schedule, diet, and supplements, as well as the duration, severity, and frequency of poor performance. Changes in muscle mass and symmetry, previous lameness, diseases, medications, and any factors that initiate the performance problem should be thoroughly documented. Changes in saddling, rider, training, and time off need investigation.

Physical Exam
A detailed physical evaluation of the muscular system includes careful inspection of the horse standing...
perfectly square for symmetry of muscle mass and evidence of fasciculations. Knowledge of normal muscle mass for that breed at that fitness level and the individual’s previous muscle mass prior to poor performance are essential. The entire muscle mass should be palpated for tone, heat, pain, fasciculations, and swelling or atrophy by comparing with contralateral muscle groups. Flexibility of head, neck, back, and limbs should be investigated through range of motion evaluation. Running a blunt instrument over the lumbar and gluteal muscles should illicit extension (swayback), followed by flexion (hogback) in healthy animals. Lateral motion through the spine can be assessed by push and pull of tuber coxae and withers simultaneously. Guarding against movement may reflect abnormalities in the pelvic or thoracolumbar muscles, or pain associated with the thoracolumbar spine or sacroiliac joints. Evidence of pain or resentment should be assessed several times to ensure it is repeatable. Blood samples should be drawn prior to any exercise for a complete blood count and serum biochemistry profile.

The horse should be observed at a walk, trot, and canter for any neurologic or gait abnormalities, the degree of over-reach from hind hoof to fore hoof impressions, rounding or hollowing of the back, degree of pushing off with the hindlimbs, facial expressions of pain, reluctance to exercise, and gait transitions. In complex cases, repeated clinical evaluations may be required, including examination of the horse under saddle. Viewing the horse under saddle with its usual rider can help to determine if saddle fit or the rider itself are contributing to muscle pain.

A full lameness exam with flexion tests is part of a muscle workup, as most poor performance issues in sport horses are not restricted to one body system. Use of bone scans to localize inflammation, local blocks to confirm the source of pain, and radiography and ultrasound examination to characterize lesions are often required. In addition, if horses have exercise intolerance, a standardized incremental exercise test that incorporates monitoring heart rate and blood lactate may be of value to assess horses for cardiovascular and metabolic derangements.

Exercise Challenge
An exercise challenge can be helpful in detecting subclinical exertional rhabdomyolysis and in observing the progression of a gait abnormality with exercise. Blood samples to evaluate peak changes in creatine kinase (CK) activity should be taken before exercise and about 4–6 hrs after but not immediately after exercise. The exercise test in unfit horses involves 2-min intervals of walk and trot for up to 15 min. Clinical judgment should be used and horses should not be pushed if they seem reluctant to continue to exercise. Rather, allowing horses to stand for a minute and then asking the horse to recommence a trot often differentiates a lazy horse from one that will continue to show a stiff and stilted gait from muscle pain. For fit horses, 4 min of walk and 11 min of continuous trot can be used. During the test, horses should be observed carefully for exacerbation of lameness, changes in impulsion, stiffness, shortened stride, and development of a sour attitude. In addition to quantifying the extent of rhabdomyolysis during mild exercise, the exercise test can be used to decide how rapidly to put a horse back into training. Horses with marked elevations in CK 4 hrs following light exercise should be very gradually reintroduced to exercise once a therapeutic regime is instituted.

A 2- to 3-fold increase in CK 4 h after exercise indicates chronic subclinical exertional rhabdomyolysis. A normal serum CK response to exercise is still compatible with myopathies such as type 2 polysaccharide storage myopathy (PSSM2), myofibrillar myopathy, and vitamin E-deficient myopathy that do not consistently disrupt the muscle cell membrane. In addition, horses with type 1 PSSM (PSSM1) and recurrent exertional rhabdomyolysis can have normal CK responses to an exercise test when on a well-controlled diet and exercise regime.

Ancillary Diagnostic Tests
Depending on the breed, hair roots or ethylenediaminetetraacetic acid (EDTA) blood for genetic testing may be reasonable next steps in investigating a myopathy. Malignant hyperthermia can cause intermittent exertional rhabdomyolysis and is found in Quarter Horse-related breeds. Genetic testing for PSSM1 is a good choice for Quarter Horse-related breeds, Belgian and Percheron draft-related breeds, and some Warmbloods (see Table 1 for breed prevalence). PSSM1 is not found in light breeds such as Arabian, Thoroughbred, and Standardbred horses. Serum vitamin E concentration is indicated in horses with reduced muscle mass or weakness or horses with little access to fresh green pastures. Whole blood selenium concentrations are indicated for horses not receiving supplementation if they are in a selenium-deficient region.

Muscle biopsy for horses with suspicion of a chronic myopathy where genetic testing proves negative, chronic muscle pain is impeding performance, or focal or generalized muscle atrophy is present. It is important to thoroughly investigate lameness before using a muscle biopsy as a diagnostic tool. This is because, for some disorders such as PSSM2, assessment of glycogen stains has relatively low sensitivity and specificity, and, therefore, muscle biopsy should only be done in the face of a high degree of suspicion of clinical disease.

For horses with atrophy, biopsies of the atrophied muscle (focal atrophy) or the sacrocaudalis dorsalis muscle (generalized atrophy) should be performed. The sacrocaudalis is often the only muscle that will show lesions of vitamin E-deficient myopathy or equine motor neuron disease. For horses with exercise intolerance or exertional rhabdomyolysis, gluteal or semimembranosus biopsies are preferable. A portion of muscle that is shipped fresh on ice...
packs and then frozen in specialized laboratories as well as a smaller portion fixed in formalin are preferred because muscle fiber-type composition (% of type 1, 2A, and 2B fibers), fiber oxidative capacity (degree of oxidative staining), lipid storage, and other metabolic parameters as well as immunohistochemistry can be assessed.

3. Differential Diagnoses

Following a complete evaluation, the origin of muscle dysfunction usually falls into one or more of the following categories:

Pain from an extrinsic source
- Muscle contusions or tearing
- Focal or generalized muscle strain from overuse
- Muscle strain secondary to skeletal pain and altered gait

Weakness
- Myogenic atrophy
- Diseuse
- Immune-mediated myositis
- Deficiency of Vitamin E
- Malnutrition/malabsorption
- Cushing’s disease

Neurogenic Atrophy
- Lower Motor Neuron Diseases (EMND)
- Trauma (focal)
- Equine protozoal myelitis (focal)
- Polyneuropathy (focal)

Inadequate oxidative metabolism
- Insufficient training of those myofibers that contribute to the expected performance leading to fatigue
- Skeletal muscle oxidative enzyme defects
- Abnormal fat metabolism: some horses lose energy and do not perform well on high fat diets

Disrupted glycogen metabolism
- PSSM1 due to GYS1 mutation or PSSM2 of unknown origin
- Depletion of glycogen from excessively low starch feeds

Disruption of excitation contraction coupling
- Malignant hyperthermia (MH)
- Recurrent exertional rhabdomyolysis (RER)

Myofibrillar disruption
- Myofibrillar myopathy (MFM)

In conclusion, poor performance can arise from sporadic focal muscle pain due to extrinsic sources as well as chronic generalized muscle pain and weakness from intrinsic sources. The foundation for determining the cause of pain or weakness is a thorough physical examination that integrates an orthopedic and neurologic examination with a systematic

<table>
<thead>
<tr>
<th>Sampling Details</th>
<th>Breed</th>
<th>Number Tested</th>
<th>Prevalence (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random sampling</td>
<td>Percheron</td>
<td>149</td>
<td>62</td>
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<tr>
<td></td>
<td>Belgian</td>
<td>149</td>
<td>39</td>
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<td></td>
<td>Haflinger</td>
<td>50</td>
<td>18</td>
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<td></td>
<td>Paint</td>
<td>195</td>
<td>7.7</td>
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<td></td>
<td>Quarter Horse</td>
<td>335</td>
<td>6.6</td>
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<tr>
<td></td>
<td>Appaloosa</td>
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<td>214</td>
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<td>Shire</td>
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<td>Clydesdale*</td>
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<tr>
<td></td>
<td>Arabian</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Norwegian Fjord</td>
<td>46</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Icelandic Pony</td>
<td>45</td>
<td>0</td>
</tr>
</tbody>
</table>

| Nonrandom sampling     | Warmbloods with potential myopathy | 253 | 6.3 |
|                        | Hanoverian                     | 214 | 0   |
|                        | Belgian Trekpaard              | 38  | 92  |
|                        | Netherlands Trekpaard          | 23  | 74  |
|                        | Comtois                        | 88  | 80  |
|                        | Breton                         | 51  | 63  |
|                        | Rheinisch-Deutsches kaltblut   | 44  | 68  |
|                        | Sud-Deutsches kaltblut         | 265 | 20  |
|                        | Swedish Ardennier              | 29  | 38  |

*Both randomized and nonrandomized samples.
examination of the musculature. Some muscle disorders cause exertional rhabdomyolysis with resultant increases in CK, whereas others cause a decline in performance due to pain or weakness. Ancillary tests such as genetic testing, exercise testing, assessment of serum vitamin E, and muscle biopsy can be helpful in diagnosing a cause for poor performance, but it is very important to put results into context with the physical exam findings and performance history.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

Dr. Valberg and colleagues own the license for PSSM testing and receive sales income from its use.

References

Survey on Thoroughbred Use, Health, and Owner Satisfaction in the First Year Following Retirement from Racing

Shannon K. Reed, DVM, MS, DACVS-LA*; Brian Vander Ley, DVM, MS, DACVP; Rhodes P. Bell, DVM, MS, DACVS-LA; David A. Wilson, DVM, MS, DACVS; Ethan Wilborn, DVM; and Kevin G. Keegan DVM, MS, DACVS

Owners of Thoroughbreds retired from racing are highly satisfied with the breed. Prepurchase examinations would be helpful in identifying issues present at retirement from racing, and veterinarians performing them should be aware of the common ailments of the breed. Authors’ addresses: University of Missouri College of Veterinary Medicine, Department of Veterinary Medicine and Surgery, 900 E. Campus Dr., Columbia, MO 65211 (Reed, Wilson, Keegan); Great Plains Veterinary Educational Center, PO Box 148, Clay Center, NE 68933 (Vander Ley); Park Equine Hospital 3550 Lexington Rd., Versailles, KY 40383 (Bell); Kentucky Equine Medical Associates, 4210 Southern Parkway, Louisville, KY 40214 (Wilborn); e-mail: reedsk@missouri.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Thousands of Thoroughbred horses retire from racing each year to private ownership outside the racing industry and many go on to second careers. Veterinarians guiding owners and potential owners of retired racehorses should be aware of the common issues those horses face after leaving racing careers.

2. Materials and Methods
A survey on use, health, and behavior was available to owners of Thoroughbreds (OTTB) that had retired from racing and regarding information on horses for the first year after leaving racing. Control data came from owners of non-racehorses. Information for racing records came from a publicly available database. Statistical analysis compared incidence of health and behavior issues between OTTBs and controls and between different racing experiences for OTTBs. Data were evaluated for common issues experienced in the first year, owner satisfaction, and effects of various factors in a racing career on issues experienced in retirement.

3. Results and Discussion
Thoroughbreds retired from racing were more likely to suffer from musculoskeletal injuries, gastrointestinal, behavioral, and foot/hoof issues than controls. Age at first and last start, number of starts, and breaks of six months or more during racing career did not affect incidence of disease, with the exception that horses with >51 lifetime starts were more likely to experience gastrointestinal disease.

Research Abstract—for more information, contact the corresponding author

NOTES
HOW TO DIAGNOSE POOR PERFORMANCE IN THE EQUINE ATHLETE

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
Evaluation of Videoendoscopic Examinations of Laryngeal Function in Juvenile Thoroughbreds: Can We Agree?

Sarah Plevin, BVMS*; and Jonathan McLellan, BVMS

Good inter- and intra-observer agreement for determining laryngeal grades using ordinal scales is lacking across all experience levels, independent of video-dependent variables. Observer agreement increased when ordinal scales were reclassified dichotomously. Authors' address: 10195 N HWY 27, Ocala, FL 34482; e-mail: infieldems@hotmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Upper respiratory tract (URT) endoscopic examination is a routine part of prepurchase examinations. The main objective was to determine the level of multi-veterinarian agreement when assessing video clips of arytenoid function.

2. Materials and Methods

Ninety-two video scopes of the URT were evaluated by 10 reviewers. Interobserver agreement for ordinal and dichotomous scales was assessed across all 10 raters using Fleiss’ kappa and between pairs in the five subgroups using Cohen’s unweighted (k) and weighted kappa (Ck). Intra-observer agreement was calculated for each reviewer using 22 repeat full-length video clips.

3. Results

Overall inter-observer agreement using ordinal scales was fair (k 0.27) to moderate (Ck 0.57). Using dichotomous scale it was good (k 0.70).

Experience level differences existed.

4. Discussion

Inter- and intra-observer agreement for arytenoid function grades using ordinal scales, ranged from fair to moderate and fair to good, respectively.

Agreement was highest using dichotomous scales and, as such, industry expectations for different levels of agreement should be discussed.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.
Review of Bisphosphonate Use in the Racehorse: Magic Bullet or Russian Roulette?

Jonathan McLellan, BVMS, DACVSMR

Until greater racehorse-specific research on the effects of bisphosphonates is undertaken, this drug class should be used with extreme caution, if at all. The ethical dilemma of using an “off-label” drug that has a known analgesic effect, has unpredictable excretion times, is difficult to detect with conventional forensic methods, remains bound to, and potentially active in skeletal tissues for extended periods of time must be considered prior to administration. Author’s address: 10196 N HWY 27, Ocala, FL 34482; e-mail: infieldems@hotmail.com. © 2018 AAEP.

1. Introduction

Bone remodeling is of great importance to several orthopedic diseases of the racehorse, and bisphosphonates, with their reported effects on bone turnover, may have the potential to alter the remodeling response. The United States Food and Drug Administration recently approved two non-nitrogenous members of the bisphosphonate drug family, clodronate and tiludronate, for the treatment of navicular disease in the horse. Currently, commercial advertisements for these recently licensed non-nitrogenous bisphosphonates appear in veterinary specific and general horsemanship publications. Nitrogenous bisphosphonates are not yet licensed in the horse but there are anecdotal reports of their off-label use in the racehorse.

With the increasing awareness of bisphosphonates among racehorse trainers, owners, and veterinarians, it is prudent to examine the existing evidence to determine if this class of drugs has a place in the off-label treatment of orthopedic disorders of racehorses.

In bone, the osteoclast-related anti-resorptive effect of bisphosphonates is well documented, but the simple assumption made by some practitioners that “by inhibiting osteoclasts we stop bone resorption which means bones are stronger” is a gross oversimplification of bone physiology and drug pharmacology. Bisphosphonates have additional anti-inflammatory and pain-relieving effects, in addition to effects in non-osseous tissue such as cartilage. Practitioners must have answers to the following questions prior to embarking in off-label bisphosphonate treatment of racehorses: What is the current evidence for use in horses and is any of the research racehorse specific? What conditions of racehorses have anecdotally been suggested for off-label treatment with these drugs and does the evidence support such use? Are there known or theoretical long-term risks to treatment? Finally, can bisphosphonates be safely used in immature horses?

2. What is the Current Evidence for Use in Horses?

The most well-reported equine studies involved administration of tiludronate for the treatment of chronic back soreness, lower hock osteoarthritis and navicular disease. These studies all yielded favorable results from blinded analysis but clinical
signs were the main determinant of success. All horses were older and none were racehorses, so extrapolation of these results to that population may be inappropriate. At least some of the positive changes seen may have been due to pain-relieving or anti-inflammatory effects of tiludronate, rather than a direct effect on bone density, which was not assessed. In another experimental study, unilateral cast immobilization was used to induce bone resorption and assess the protective effect of tiludronate. From this equine research, it is clear that serum biomarkers (CTX-1) of bone resorption are significantly reduced following treatment with tiludronate. Several other studies have been undertaken, and other members of the family, such as the nitrogenous bisphosphonates pamidronate and zoledronate, have been investigated for short-term safety and usefulness in the horse. In summary, equine-specific investigations of bisphosphonates are sparse compared with the human literature, where these drugs have been extensively studied since the 1960s.

Many questions related to bisphosphonate use in the horse have, therefore, not yet been answered by scientific evaluation in this species. In other species, many members of the bisphosphonate class have been studied and the pharmacokinetics and physiologic effect of each drug may be different. Additionally, inter-species differences may exist and there is no population directly comparable to the racehorse. For these reasons, until racehorse-specific research is undertaken, extrapolation from experimental and clinical research in other species must be undertaken with caution. There are very few racehorse-specific reports of bisphosphonate use in the literature. One "how to" paper presented at the 2012 AAEP convention, described 5 racehorses with varying severity of dorsal metacarpal disease (bucked shins) treated favorably with a combination of weekly intravenous (IV) regional perfusion with 50 mg of tiludronate, shockwave therapy, rest, and controlled exercise. It is impossible to ascertain the influence of tiludronate on healing due to the presence of multiple concurrently used modalities, a limitation acknowledged in that manuscript. A more recent article described the standing magnetic resonance imaging (MRI) appearance of 4 Japanese racehorses with proximal suspensory avulsions, which received weekly IV regional perfusion with 50 mg of tiludronate subsequent to injury. Three of the 4 horses demonstrated improved MRI signal and successfully returned to training. It was surmised that the speed of healing viewed with MRI was "quicker" than that reported in another follow-up study using rest alone. It should be noted, however, that the comparison was between only 1 horse and the manuscript concluded that no results could be drawn regarding the influence of tiludronate due to low numbers, lack of study control, and insufficient existing evidence regarding the follow-up MRI appearance of such lesions in horses not treated with tiludronate.

3. What Other Conditions of Racehorses Have Been Suggested for Off-Label Treatment and What is the Evidence?

In addition to the injuries reported in the two case series outlined above, some veterinarians have suggested that bisphosphonates may be useful in the racehorse for the treatment or prevention of other diseases, specifically reduction in stress fracture risk, treatment of palmar/plantar osteochondral disease (POD), sesamoiditis/suspensory branch insertional enthesis, osteoarthritis (OA), and subchondral bone cysts. Rather than list the specific modes of action of bisphosphonates, it is probably of more benefit to report the evidence of how bisphosphonates may influence each disease in an attempt to explain why bisphosphonates may, or may not, be an appropriate treatment option for each disease.

Stress Remodeling

Several diseases in the racehorse arise from an inappropriate bone remodeling response and can be considered under the heading “stress remodeling.” Examples include stress fractures of the tibia, humerus, scapula, or pelvis; sclerosis of the third carpal bone; and POD.

This is a common source of lameness in the racehorse and typically accounts for either several months out of training or, worse, can lead to catastrophic injury. It can affect almost any bone as a result of the failure of functional adaptation to high strains or strain rates placed upon it. There are two parts to the theoretical use of bisphosphonates in this type of injury: prevention and repair.

Regarding prevention, the theoretical reasoning for “prophylactic stress remodeling/fracture treatment” has arisen from a lack of understanding of bone physiology among some practitioners. Because stress fractures are a propagation of stress remodeling and the first stage of remodeling is bone resorption, some practitioners have anecdotally suggested that “if bone resorption is halted, the bone will not become weakened and therefore stress fractures will not occur.” It is true that in humans, higher serum levels of biomarkers of bone resorption have been identified prior to subsequent stress fracture development, thus it is conceivable that halting this pathway may be desirable. This theory, however, is not borne out by what is known about bone physiology in other species. Beagles administered high doses of risedronate and alendronate demonstrated microdamage accumulation and the bone was deemed to be weaker, with 19% less energy required to break a rib. In a rat ulna stress-fracture model, the nitrogenous risedronate failed to prevent stress fracture occurrence and actually delayed healing, as evidenced histologically at 10-weeks post-fracture. In human army recruits, prophylactic risedronate administration did not decrease the risk of subsequent stress fractures and there was a (statistically insignificant) trend toward delayed healing in the treated group. Although
this has not yet been evaluated in the horse; these studies suggest that prophylactic treatment of bones under high strain rates, such as in the racehorse, may actually weaken bone and predispose to stress fracture, the opposite of the intended effect.

It is important to realize that microcracks occur in bone due to normal (or training induced) stresses and strains. In contrast to complete fractures, the only way that bone can heal these microcracks is to initiate resorption as the first step in the healing process across the crack. Osteoblasts then form new, osteonal bone across the fracture line and the bone matures as healed, fully functioning bone. Interestingly, as the osteoblast “follows” the osteoclast across the fracture, inhibition of the osteoclast actually results in decreased bone formation up to 44% in one stress-fracture-repair study using alendronate. In other words, if the osteoclast cannot initiate the healing of these microcracks, they will ultimately propagate.

To complicate our understanding of the effects of these drugs, bisphosphonates may inhibit the healing of microcracks by a “protective” effect in specific cells that do not internalize the drug such as the osteocyte. This is important because the role of the osteocyte in bone homeostasis is to sense changes in its environment and, in areas of impending stress fracture, osteocytes undergo apoptosis that initiates the cascade of osteoclast development and recruitment. The osteocyte can, therefore, be considered the orchestrator of stress fracture repair. It is believed that bisphosphonates, by having an anti-apoptotic effect on the osteocyte, inhibit osteoclast recruitment and decrease the ability to repair microcracks. With osteoclast inhibition, the bone collagen becomes older, more mineralized, and contains less water. As a result, the bone mineral density and stiffness increase but the toughness (the bone’s ability to yield without failure) decreases and this may predispose the bone to propagation of microcracks. Bisphosphonate-treated bone, for want of a better description, has the material properties of a concrete block: very strong but very easy to fracture. By interfering with the homeostasis of bone mineral density, there is the risk that we may actually create long bones that are predisposed to fracture. The dose, frequency, and individual drug at which these theoretical risks may be encountered has not been evaluated in the horse. It has been postulated that the distribution of bisphosphonate is not uniform but is higher in actively remodeling bone and higher in cancellous than cortical bone that may mitigate some of the risk regarding long bone stress fractures. However, all bones in the racehorse are undergoing active remodeling as a consequence of their training regimes and, thus, uptake may be more uniform than is seen in humans. Until racehorse-specific research is undertaken, the uptake pattern of bisphosphonates in this demographic is unknown.

Regarding repair of stress fractures, in humans, it has been suggested by some that bisphosphonates aid the healing of stress fractures. Although, the use of bisphosphonates to treat human stress fractures in athletes is controversial, with the general recommendation being that until well-designed safety studies are undertaken, it is prudent to limit the use of bisphosphonate for the treatment of stress fractures. Bisphosphonates decrease bone remodeling and decrease the rate of stress fracture repair, as assessed histologically. Results of nuclear scintigraphy or radiographic examinations may be misleading regarding the quality of healing occurring in the cortex at the level of the stress fracture. One case report identified that 4 (of 5) human athletes treated post-injury with pamidronate resumed training in a pain-free manner within 72 hours of scintigraphic confirmation of tibial stress fractures and that all patients resumed training within a 3-week period. However, there are weaknesses in this case report and it should not be extrapolated to racehorses. The strain forces on the tibia of a training racehorse are not comparable to those of a human runner and attempting to train a racehorse with a long bone stress fracture so soon after diagnosis is a recipe for disaster.

Palmar/Plantar Osteochondral Disease

POD (stress remodeling/bone bruising) has recently received much attention in the racehorse. Like stress fractures, POD is also the result of a failure of bone to adapt to training loads. The palmar/plantar subchondral bone attempts to adapt by becoming denser and eventually more brittle, leading to the potentially irreversible collapse of the subchondral bone and clinical signs of joint effusion, pain, and lameness. There is limited evidence to support the use of bisphosphates in POD and a recent Havey-meier meeting report recommended that bisphosphonates had no place in the treatment of this disease based on current evidence. As the disease is a result of increased bone density, it seems counterintuitive to use drugs that are known to increase bone mineral density further. In fact, in humans, overuse of pamidronate resulted in “marble bone disease” (osteopetrosis) in a child, an extreme case of these drugs resulting in dense, brittle bones. Additionally, tiludronate has anti-vascular endothelial growth factor properties that may impede vascularization and, at least in theory, may compound the disease because it has recently been cited that impaired blood supply may be a factor in its development. For these reasons, drugs such as bisphosphonates, which increase bone density, slow the rate of bone turnover, and have the potential to impair blood flow are probably contraindicated in POD.
Sesamoiditis and Suspensory Enthesis

Insertional injuries of the suspensory ligament are well documented in the racehorse.20 Pain arises due to inflammation between the sesamoid bone and the suspensory branch or at the proximal origin of the suspensory ligament. This inflammatory cycle leads to lysis of bone that is intermittently painful, results in local swelling, and can often be seen radiographically as enlarged vascular channels on the sesamoids24 or lysis/sclerosis on the palmar surface diagnostically as enlarged vascular channels on the third metacarpal/metatarsal bones (MC/MT 3). In 2001, the European Agency of Medicinal Products cited insertional sesamoid/suspensory branch injury as a condition that could be treated with tiludronate.25 By reducing osteoclastic resorption, it was proposed that pain would be relieved, insertional Sharpey fibers preserved, and the cyclical inflammatory nature of the disease arrested, although there is no published evidence to support this theory. The risk in the racehorse is that it is not known whether the abatement of clinical signs is due to analgesic effects of bisphosphonate or a true resolution of the disease process. Similar to the situation with stress fractures, it is possible that treatment is effective at reducing clinical signs without resolving the condition, potentially predisposing the racehorse to a future failure of the suspensory apparatus. A separate condition, sesamoid fracture, is a result of the failure of bone to adapt to training forces. It is possible that bisphosphonate treatment may increase bone density, increase brittleness, and ultimately lead to sesamoid fractures; thus, treating for one disease may predispose to another. These risks have not been demonstrated and they remain theoretical concerns. This may be especially important as some practitioners use bisphosphonates to treat sesamoiditis in yearling Thoroughbreds based on the anecdotal assertion that the radiographic appearance of sesamoiditis appears to resolve. The ethical implications of the potential long-term risk of such off-label use should be considered, and, again, bisphosphonate use for this condition in the racehorse must be discouraged until more critical research has been undertaken.

Osteoarthritis

Non-racehorse studies have demonstrated a positive effect of bisphosphonate on clinical signs related to OA of the lower hock joints.3,7 In humans, intra-articular (IA) clodronate was considered as effective a pain reliever as IA hyaluronic acid for knee OA.26 There are many mechanisms of therapeutic action:27,28 bisphosphonates may stabilize the subchondral bone or even protect chondrocytes from undergoing apoptosis. They may chelate the zinc required for pro-inflammatory matrix metalloproteinase (MMP) function, in addition to reducing the concentration of inflammatory cytokines within the joint. In both humans and horses, it is generally accepted that bisphosphonates can result in amelioration of clinical signs due to OA.3,7,29 It is also known that there is a dose-dependent response in equine chondrocyte explants: low doses decrease apoptosis and sulfated glycosaminoglycan (sGAG) release, whereas higher doses result in increased sGAG release and MMP concentrations.28 At this time, it is considered that IA use of tiludronate may lead to concentrations that are potentially damaging to cartilage, although very low doses may be protective. However, care must be taken in the extrapolation of these experimental data to clinical cases. Tiludronate is also known to induce synovial inflammation when administered IA and the drug will enter the systemic circulation from this route.30 Systemic or low-dose IV regional perfusions may be considered safe to chondrocytes, but high dose regional perfusions may be toxic to chondrocytes and care should be used when calculating which dose to use and which route to administer.31 Further investigation in larger numbers of horses is warranted and, until then, IA use should be considered experimental.

Subchondral Bone Cysts

Developmental subchondral bones cysts secrete pro-inflammatory prostaglandin E2, nitric oxide, and neutral MMPs, which result in pain and recruitment of osteoclasts, resulting in cyst expansion.32 There is a theoretical rationale for the use of bisphosphonates in such cases because this class of drug is known to be antiresorptive, anti-inflammatory, and to have anti-MMP effects.17 This potential use has not been described in the current literature and there are potential negative effects to healthy chondrocytes, in addition to potentially adverse systemic effects as outlined earlier.

4. Are Bisphosphonates Safe in the Juvenile Horse?

Licensed bisphosphonates are only labeled for use in horses over 4 years old and the US Food and Drug Administration has actually issued warnings against its use in horses younger than 4 years old. Similarly, in the United Kingdom, no racehorse is permitted to receive bisphosphonate prior to reaching 42 months of age. This was revised upward from 36 months, within the last year. This generalization derives from experience with this drug class in humans. Even though bisphosphonates have been extensively studied in children since the 1960s, there is a lack of age-specific safety and efficacy data and controversy exists regarding childhood use. The general recommendation is that use should be restricted to specific medical conditions such as osteogenesis imperfecta, compassionate ameliorative use, or research.16,33 A growing animal (rabbit) model study demonstrated a transient effect on physeal cell morphology and a 3% decrease in long bone length, but this has not been borne out in humans.34 It is difficult to extrapolate across species, however, because all human children treated were suffering from specific bone disorders and this is not the case in the racehorse. Equine-specific research has
demonstrated that healthy, trained juvenile horses have higher levels of bone remodeling biomarkers than those that are exercise-restricted. Indeed, increased bone remodeling is a prerequisite for a healthy, athletic skeleton. Those same biomarkers are also increased in racehorses in training compared with non-training controls. Of importance, it has been shown that administration of tiludronate decreases the serum concentrations of these biomarkers. One can infer from these studies that a certain level of bone remodeling is necessary in the juvenile horse and that tiludronate, by reducing this turnover, may have a negative influence on appropriate skeletal development in the young athlete. For this reason, use of bisphosphonates is generally discouraged in adolescent human athletes, the group most comparable to juvenile racehorses. Additionally, human females of potential childbearing age are discouraged from using bisphosphonates due to the potential for fetal accumulation of the drug, leading to fetal skeletal abnormalities. No case report exists to prove the clinical significance of this issue, although the potential risk is often cited and should be considered by equine veterinarians when treating female patients.

5. Analgesic Effects of Bisphosphonates
The resolution of pain demonstrated so quickly after bisphosphonate administration in human athletes has potential implications for the use of bisphosphonates in all competition horses but especially the racehorse due to the intensity of training and racing. In humans and horses, it has been postulated that active bone resorption may be painful and that inhibition of this process may result in pain relief. It is believed that by reducing the development of an acidic environment at the ruffled border of the osteoclast, acid-sensitive ion channels within free nerve ending are not activated, thus pain is reduced. That is likely part of the mechanism of analgesia, but there are multiple experimental reports of the pain-relieving effects of bisphosphonates independent of osteoclast inhibition, and these analgesic effects may occur at lower than typical therapeutic doses. Tiludronate reduces the release of the inflammatory mediator nitric oxide and other inflammatory cytokines from macrophages. Bisphosphonates may also have direct inhibitory effects in developing glial nerve cells and, in dogs, spinal levels of substance P were reduced in an experimental OA model. Although the nitrogenous bisphosphonates may have more potent anti-resorptive effects, the non-nitrogenous tiludronate and clodronate may have more potent anti-inflammatory, analgesic effects. Clodronate has been shown to decrease levels of several MMP enzymes in vitro and even demonstrated an analgesic effect when injected directly into the cerebral ventricles of mice, perhaps through direct interaction with neurons. Relating these potential analgesic effects to the existing equine clinical studies suggest that extreme caution should be exercised when deciding upon treatment of racing Thoroughbreds with stress fractures or other cyclical fatigue injuries. If clinical signs alone are being used to assess improvement, a situation could arise where a horse “appears” free from lameness and, therefore, “healed”. It is possible, however, that the horse may be benefiting from the analgesic effects of bisphosphonate while actually having a delayed bone-healing response due to bisphosphonate.

6. Research into Withdrawal Times
Bisphosphonate-analgesia represents a significant ethical dilemma for the industry, magnified by the fact that these drugs have extremely short serum and urine half-lives and are difficult to extract from bone for analysis. Horses may be trained, raced, or sold while bisphosphonates are still active within the animal and the only way to identify them is by accessing the medical record of the attending veterinarian. For this reason, and the effect on bone remodeling, it is of great importance to establish industry guidelines for withdrawal times for this class of drug. One recently published field population study was undertaken to assist with determining “real world” withdrawal times for horses treated with tiludronate at a dose of 1 mg/kg IV. Compared with a previously reported experimental study, plasma elimination half-life was considerably longer and a significant difference was observed between “rested” horses and “in training or competition” horses, with reported T1/2 of 370 hours in training horses compared with 289 hours in rested horses. No explanation was given for this 28% delay in plasma elimination half-life in training horses, but the authors concluded that it most likely represents the increased bone turnover in training compared with resting horses. Their conclusion was that, although most horses should have less than 2 ng/ml of tiludronate in their serum by 25-days post-injection, results could be highly unpredictable, especially in training horses where elimination is delayed due to active bone remodeling. Regardless of the plasma elimination half-life, bisphosphonates remain active within the bone for extremely long periods relative to their plasma half-lives. The drug may stay “buried” within the bone matrix until it is recruited in an area of active bone turnover. Tiludronate has been identified in the bones of treated horses as far as six months post-treatment and, in humans, several of the newer generation nitrogenous bisphosphonates have bone durations of up to 10 years. Thus, even if serum or urine testing is used, the drug may still be having a physiologic effect in a horse, which tests negative to these forensic methods. Recently, there has been discussion (working group chaired by Dr. Jeff Berk) regarding labeling bisphosphonates so that they may, at the very least, be identified within the bone on post-mortem examinations to investigate their role in musculoskeletal injury in treated racehorses. The British Horseracing Association up-
dated their policy on bisphosphonate use effective August, 2017 and their "stand down" rule states:41

"11.B.2 The horse must not have been administered any bisphosphonate on the day of the race or on any of the 30 days before the day of the race in which the horse is declared to run."

"Due to their complex nature and action, the excretion of bisphosphonates may be unpredictable, leading to considerable variation in excretion times. This variability may be increased when bisphosphonates are administered to horses with ongoing musculoskeletal disease process, including the possibility that bisphosphonates may be released from bone at a period remote from initial administration. As such, it cannot be guaranteed that future musculoskeletal disease processes will not result in an Adverse Analytical Finding." Such concise warnings have not yet been adopted by racing jurisdictions here in the United States; however, these concerns should be considered prior to initiating off-label treatment in the racehorse for those practitioners who want to treat horses while "out of race-training".

7. Conclusion

Bisphosphonates may be useful in the treatment of specific orthopedic conditions in the horse, and several products have been evaluated, considered safe in the short term, and have received disease-specific licenses for equine use. No longitudinal study, however, has evaluated the effects of bisphosphonate use in the training or racing of Thoroughbreds. Therefore, off-label use of bisphosphonate in the racing and juvenile Thoroughbred should not be undertaken without careful consideration. Current evidence, albeit in other species as reported here, suggests that bisphosphonates may be contra-indicated in many orthopedic conditions of the racehorse, especially in the younger patient. There is insufficient evidence for the efficacy or long-term safety to recommend bisphosphonate use in this population. Racehorses in training are exposed to tremendous skeletal strains that necessitate bone modeling and remodeling throughout their careers. Attempting to "control" bone metabolism in such an empiric way, particularly with an extremely long-lasting drug, may create more harm than good in this demographic, and until greater racehorse-specific research on the effects of bisphosphonates is undertaken, this drug class should be used with extreme caution, if at all.

The ethical dilemma of using an off-label drug that has a known analgesic effect, has unpredictable excretion times, is difficult to detect with conventional forensic methods, yet remains bound to and potentially active in skeletal tissues for extended periods of time must be considered. This is especially important to the Thoroughbred industry, where horses may change ownership frequently.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnote

HOW TO DIAGNOSE POOR PERFORMANCE IN THE EQUINE ATHLETE


Grade 3 Left Laryngeal Movements in Young Thoroughbreds Do Not Impair Future Racing Performance

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Future racing performance is not significantly different between horses with laryngeal movements grade 3 and <3. Authors’ addresses: Ballarat Veterinary Practice, Miners Rest, Victoria, Australia (Anderson); Hope Bloodstock, Cambridge, New Zealand (Hope); Massey University, Palmerston North, New Zealand (Cogger); e-mail: ba@bvp.com.au. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
A 5-point grading system for laryngeal movements (LMs) is used at Thoroughbred sales in New Zealand. Grade 4 and 5 horses fail (arytenoid cartilage cannot be fully abducted) and likely have significant recurrent laryngeal neuropathy. Grades 1, 2 and 3 LM pass. Grade 3 LM show resting arytenoid asymmetry and full arytenoid abduction is achieved but not sustained. We hypothesized that there would be no difference in racing performance between horses with grade 3 LM and those with <3 LM.

2. Materials and Methods
Horses with left grade 3 LM were compared with horses with <3 LM from the same sale. For continuous measures of racing performance, the significance of LM grade (<3/3) was determined using the Kruskal-Wallis test. Categorical measures of racing performance and LM score <3 and 3 was assessed using the $\chi^2$ test statistic.

3. Results and Discussion
Between 2003 and 2014 10,862 yearlings and 1,905 2-year-olds were scoped. Of these, 917 had an LM grade of 3. Comparison with 1,601 horses with LM <3 showed no significant difference in number of starts ($P = 0.28$), number of race wins ($P = 0.59$), prize money ($P = 0.78$), strike rate ($P = 0.86$), or ratings ($P = 0.83$). The proportion of horses that had started in a race did not differ between the two grades ($P = 0.38$), nor did the proportion of horses that won a race ($P = 0.34$).

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

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The Authors have no conflicts of interest.
Comparison of Ceftiofur, tris-EDTA or Combination in Treatment of Biofilm Associated Pseudomonas Infections

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A combination of ceftiofur and tris-EDTA was more effective in treatment of biofilm-associated *Pseudomonas aeruginosa* uterine infections as compared with ceftiofur or tris-EDTA alone. Authors’ addresses: Summit Equine, 29895 NE Wilsonville Rd., Newberg OR 97132 (Ferris); Departments of Microbiology, Immunology and Pathology (G Borlee, B Borlee), and Equine Reproduction Laboratory (McCue) Colorado State University, Fort Collins, CO 80523; e-mail: rferris@summitequineinc.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Bacteria can produce a biofilm matrix to become more tolerant of antimicrobial treatment.

2. Materials and Methods
Twenty mares were inoculated with *Pseudomonas aeruginosa* known to create a biofilm in vivo. Following establishment of the infection the mares were allocated randomly to the following treatment groups (n = 5): untreated control, ceftiofur, tris-ethylenediaminetetraacetic acid (EDTA) or a combination of ceftiofur and tris-EDTA. Fourteen days after the last treatment ultrasound of the uterus, endometrial culture and cytology via double guarded swab, and endometrial biopsy were performed. All treatments and interpretation of samples were performed in a nonbiased manner. Numerical data were compared using Student’s t-test, categorical data were compared using Fisher’s exact test.

3. Results
Mares treated with ceftiofur plus tris-EDTA had significantly less intrauterine fluid (P < .05), an absence of *Pseudomonas aeruginosa* on subsequent uterine culture (P < .05), significantly less (P < .05) white blood cells on endometrial cytology, and significantly less (P < .05) adherent material on the surface of the endometrium on histopathology of uterine biopsy samples as compared with untreated control mares or mares treated with either ceftiofur or tris-EDTA alone.

4. Discussion
This study indicates that combination of ceftiofur and tris-EDTA are more effective at treating biofilm-associated *Pseudomonas aeruginosa* uterine infections as compared with ceftiofur or tris-EDTA alone.

Acknowledgments
Declaration of Ethics
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Conflict of Interest
The Authors have no conflicts of interest.

Research Abstract—for more information, contact the corresponding author

NOTES
1. Introduction

Knowing the exact location of a retained testis or testes prior to cryptorchidectomy has many benefits. A well-informed surgeon can choose the most optimal, least invasive method for cryptorchidectomy. Eliminating the need to search for a retained testis during the procedure significantly reduces the time of anesthesia and frequency of complications. The authors have previously reported that approximately 11% of cryptorchidectomies (n = 157) performed in the Large Animal Hospital, University of Florida between 2008 and 2015 were converted from abdominal to inguinal (n = 15) or from inguinal to abdominal (n = 2). Locations of the retained testes were not determined prior to these surgeries. Similar rates of conversion of surgical method were reported by the Ontario Veterinary College (8%; n = 5 of 60). Furthermore, two to three attempts (separate surgeries) to remove retained testes were reported in horses with cryptorchidism caused by a failure of regression of the cranial suspensory ligament. Multiple surgeries or unnecessary conversions of surgical method during cryptorchidectomy are not in the best interest of the patients; thus, it is highly recommended to include in the thorough evaluation of a horse the identification of an exact location of the retained testis.

This manuscript describes, based on the authors' clinical experience, a technique to localize the retained testis in a cryptorchid horse using ultrasonography.

2. Restraint and Sedation

Before evaluation, the cryptorchid horse is placed in stocks and sedated with a combination of a2-agonist and an opiate, such as detomidine hydrochloride (0.01 mg/kg, IV) and butorphanol tartrate (0.01 mg/kg, IV). Occasionally, N-butylscopolaminum bromide is also administered (0.2 mg/kg, IV) to abate gastrointestinal peristalsis and decrease pressure during rectal manipulation.

3. Initial Evaluation

Visual inspection and manual palpation of the inguinal region are performed first. There may be a fully descended testis in one hemiscrotum and no scrotal testis on the other side, or no scrotal testes at all. Certain clues can be obtained on visual inspection, such as postsurgical scars, the presence of one
descended testis, and the lack of a scrotum but a small bulge present at the external inguinal ring. To palpate the epididymis or the retained testis within the inguinal canal, one to four fingers are inserted into the external inguinal ring. Caution must be observed, since some horses will strongly object to this part of the evaluation. During palpation, the retained inguinal testis is often discovered within the inguinal canal or just outside the external inguinal ring (“high flankers”). However, differentiation between the retained testis and the epididymis, the bulb of the gubernaculum, or subcutaneous fat may be difficult during manual palpation, which leads to errors. Therefore, always follow manual palpation with ultrasonography to visualize characteristic testicular and epididymal structures.

### 4. Equipment

Ultrasonic (US) evaluation of cryptorchid horses can be performed with a portable ultrasound machine of the type used for routine reproductive evaluation of mares. The ideal machine for this application has curvilinear (convex) and linear transducers with a broad range of frequencies, between 3.5 and 10 MHz.

### 5. Inguinal US Exam

Before the exam, the skin is generously sprayed with 70% ethyl or isopropyl alcohol, or US gel is generously smeared on the inguinal area. A curvilinear (convex) or linear transducer is placed in a longitudinal orientation over the external inguinal ring, and all structures present within the inguinal canal are visualized (Fig. 1A). The US beam should be directed dorsolaterally, following the natural direction of the inguinal canal. If the retained testis is not found within the inguinal canal, the scrotal and connective tissues abaxial to the penile shaft and external to the external inguinal ring are also systematically examined (Fig. 1B). High-frequency US beam (5–10 MHz) is preferred for superficially positioned structures (Fig. 1C), while low-frequency beam (3.5 MHz) is preferred for structures positioned more deeply (Fig. 1D). The operator must be aware that a retained testis is less echogenic than a normally descended testis. Furthermore, the inguinal testis is often slightly misshapen due to the tight space within the inguinal canal. However, the characteristic hyperechoic appearance of the tunica albuginea, as well as presence of the central
vein, helps to properly identify the retained testis (Fig. 1, A–C).5

If the retained testis is not found in the inguinal region, suspect complete or incomplete abdominal cryptorchidism. In such cases, perform transabdominal or transrectal US exam, or both. While transabdominal US is noninvasive, the authors prefer transrectal US. Various regions of the abdomen are systematically scanned using transabdominal ultrasonography to search for the retained abdominal testis, which is often time-consuming. Transrectal US, by contrast, allows tracing the vas deferens all the way to the testis, which significantly shortens the examination time required. In more challenging cases, use a combination of both techniques.

Fig. 2. US images illustrating transrectal US vas-tracing technique of identifying retained abdominal testis.

Fig. 3. Series of US images (from A to D) illustrating the transrectal US vas-tracing technique of identifying the retained abdominal testis that shows all anatomical elements of the reproductive tract that can be visualized during this procedure: ampulla, narrow part of the vas deferens, epididymal tail, epididymal body, blood vessels, testis. Note that not all anatomical details are visualized during each examination.
6. Transrectal US Exam

Before transrectal US, always perform a manual examination “per rectum.” A pelvic urethra is identified first, followed by both ampullae of the vasa deferentia that are located at the neck of the bladder, and the vaginal rings are identified last. Carefully examine the vaginal rings for the presence of any palpable structures that enter the inguinal canals. Once palpation “per rectum” is completed, the linear US transducer is introduced into the rectum, and a longitudinal image of the pelvic portion of the urethra is visualized. Next, the transducer is moved cranially and laterally to assess the size and ultrasonographic appearance of the prostatic lobes located on both sides of the neck of the urinary bladder. A small and inactive prostate is characteristic of long-term geldings, whereas a large prostate with numerous spaces filled with prostatic secretions is found in intact stallions as well as in the majority of cryptorchid horses. In order to localize the retained abdominal testis, the vas deferens is traced using ultrasonography. At first, visualize the ampulla of the vas deferens on top of the urinary bladder, as previously described. Then, trace the ampulla as a guide toward the retained testis. In the intact stallion, inguinal cryptorchid, or incomplete abdominal cryptorchid, the ampulla gradually bends ventrally toward the vaginal ring, while in complete abdominal cryptorchids, it runs cranially and without bending. Slowly follow the vas deferens with the US transducer, visualizing longitudinal or cross-sectional images (Fig. 2). While the ampulla is relatively easy to trace, the narrow portion of the vas deferens is more challenging; tracing this portion requires some practice and good-quality equipment. Higher frequencies, 7–9 MHz, are preferred in this part of the examination. In horses with complete abdominal cryptorchidism, the vas deferens runs straight forward, cranio-laterally, or craniodorsally. Therefore, the direction for tracing the vas deferens may need several corrections. The result of successful tracing is to first visualize the retained epididymis and, right behind it, the retained testis (Fig. 3). This vas-tracing technique is particularly useful in horses with retained testes localized deep in the abdomen, at the caudal pole of the kidney. However, this technique is also helpful in localizing and visualizing inguinal (Fig. 4) and incomplete abdominal testes. The most challenging task is to find an abdominally retained testis after an unsuccessful surgery that led to the removal of the epididymal tail only, since the vas deferens is then disconnected from the testis and may become more mobile within the abdominal cavity. Surprisingly, the authors have found the retained testis in close proximity to the transected vas deferens in several horses using the described vas-tracing technique (Fig. 5).

7. Transabdominal US Exam

If the retained testis is not found using the previously described technique, perform transabdominal US as previously described. In addition to the inguinal area, evaluate the caudal aspect of the abdomen, from the midline to the fold of the flank, and the lateral aspect of the flank. For this examination, use a curvilinear 3.5-MHz transducer first aimed at the urinary bladder. Move the transducer cranially while scanning from the midline to the lateral aspect of the abdomen. Perform this examination slowly, meticulously, and in a well-organized fashion. Distinguishing between the retained testis, which is quite mobile, and the continuously moving intestines is not easy and requires patience. Most testes are visualized on the ventral abdominal wall, near the urinary bladder, lying between the intestinal loops or colon haustra (Fig. 6). Other testes are identified in the caudal aspect of the mid-abdomen.
8. Results

The authors of this paper evaluated 26 cryptorchid stallions between 2015 and 2017 at the Large Animal Hospital, College of Veterinary Medicine, University of Florida. The locations of 27 of 30 retained testes in 24 stallions were correctly determined. The locations of two abdominally retained testes in one horse were not determined due to the cystic malformation of these testes, which distorted their US appearance. One testis was not found using ultrasonography or by laparoscopic evaluation of the abdomen. The testicular tissue in this horse was perhaps hypoplastic and too small to be visualized or has fused with other organs, such as the spleen.  

9. Conclusions

Ultrasonography revolutionized the ability to localize retained testes in cryptorchid horses. While equine veterinarians use ultrasonography every day in their practice, ultrasonographic evaluation of cryptorchid stallions is rarely performed, despite its obvious benefits. According to numerous published reports as well as the authors’ clinical experience, ultrasonographic exam of cryptorchid stallions can be done effectively and safely. This manuscript describes methods preferred by its authors; other clinicians, however, may have their own preferences and approaches to evaluating cryptorchid stallions. The only way to become proficient in this diagnostic method and develop a preferred technique is to perform it numerous times to gain experience and confidence.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References

How to Manage the Post-Partum Mare with Metritis—Lessons Learned from a Retrospective Bacteriological Study

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1. Introduction

Metritis is one of the most common puerperal diseases affecting the mare.1 Clinical signs become evident within the first week postpartum and life-threatening complications can quickly develop.1,2 Treatment includes systemic antibiotics, uterine lavage, oxytocin, anti-inflammatory and anti-endotoxic drugs.

While Gram-negative bacteria are usually associated with endotoxemia,3,4 a wide variety of organisms have been recovered from the uterus of mares with metritis.5 It is generally accepted that mixed bacterial infections are common in mares with metritis.6 In practice, uterine cultures are rarely obtained from mares with metritis, and antibiotic choice is most often empirical targeting broad spectrum pathogen coverage. The most commonly used antimicrobials include a combination of gentamicin and penicillin, or potentiated sulfonamides.1–6 Because anaerobic bacteria can be involved in some cases, metronidazole is sometimes included in the therapy.6

While antibiotic selection would ideally be based on bacteriological tests or available data from published studies, the literature is scarce in retrospective studies than can guide treatment decisions based on evidence in mares with metritis.7 The present paper provides information on how to manage mares with postpartum metritis, with emphasis on data from bacteriological tests to help guide antibiotic selection.

2. Materials and Methods

Evaluation of the mare should include a complete history of past reproductive and nonreproductive conditions. Special attention should be paid to previous use of antimicrobials, which may affect the sensitivity pattern of the bacteria isolated. A complete physical examination is performed, including evaluation of rectal temperature, heart rate, respiratory rate, mucous membranes, and hydration status. Complete blood cell count and blood chemistry evaluation are performed. A genital examination should include a vaginal speculum exam to determine presence of lacerations, discharge, or fetal membrane remnants. In addition, palpation and ultrasound per rectum are performed to evaluate uterine size, tone, and contents. Presence of an enlarged, thin-walled, and atonic uterus on palpa-
tion per rectum, a moderate-to-large amount of intrauterine fluid on ultrasound per rectum, a fetid, brownish-red-to-purulent vulvar discharge, and signs of sepsis are considered an indication of metritis. Transabdominal ultrasound and abdominocentesis are indicated to rule out possible uterine tears occurring at parturition.

On presentation, a uterine sample is obtained for bacteriological culture and sensitivity test. Before sample collection, the vulva is scrubbed with detergent and rinsed with water until clean. Samples of uterine contents are collected transvaginally with a sterile double-guarded swab. The internal sheath and then the swab are exteriorized through the guard within the lumen of the uterine body, rotated for 5 seconds against the endometrium, and then retracted into the guard before removing from the reproductive tract. Immediately after collection, the swab is placed in sterile Stuart transport medium and transported to the laboratory at room temperature for processing the same day of collection, or cooled for processing the day after collection.

Empiric treatment is initiated after evaluation with the goals of evacuating toxic uterine contents, controlling bacterial growth, and preventing complications (i.e., septicemia, edotoxemia, laminitis). Treatment includes uterine lavage, antimicrobials, and anti-inflammatories. Uterine lavage is performed by infusing warm saline solution or tap water into the uterus, and siphoning fluid out. Homemade saline solution (35 g table salt in 4 L of tap water) can be pumped into the uterus (5–10 L at a time) through a clean stomach tube, and the lavage is repeated until the effluent is clear. Iodine povidone solution (2%, weak tea color) can be added to the fluid as an antiseptic. The need to repeat the lavages once or twice daily is determined by clinical signs, ultrasonographic evaluation of intrauterine fluid, and presence of fetid vulvar discharge. Uterine lavage is contraindicated in mares with uterine tears since it will result in leakage of septic uterine contents into the abdomen. Overdistension of the uterus during lavage may also exacerbate small uterine tears that may have occurred at parturition. Oxytocin (5–20 IU, IV or IM, every 2–6 hours) is administered to induce myometrial contractions and aid in uterine evacuation.

Broad spectrum antibiotic treatment is also provided for at least 5 to 7 days. Mares are typically initiated on a combination of potassium penicillin (22,000 IU/kg, IV, every 6 hours) and gentamicin (6.6 mg/kg, IV, every 24 hours). In cases where signs of endotoxemia or septicemia have not developed, the mares may be treated with trimethoprim/sulfamethoxazole (25 mg/kg, PO, every 12 hours). If the mare’s clinical condition deteriorates in spite of treatment, resistance to antimicrobials is suspected and the antibiotic selection may change. Once the results of the bacteriological tests are reported, the antibiotic may be changed based on the sensitivity test. Response to treatment is monitored daily with complete physical exams, palpation and ultrasound per rectum. Blood work is also repeated at regular intervals.

Anti-inflammatory drugs may be used. Given that non-steroidal anti-inflammatory drugs (NSAIDs) may inhibit prostaglandin release, uterine contractions may be less effective in mares treated with anti-inflammatory drugs, like flunixin meglumine (1.1 mg/kg, IV, every 12 hours), leading to impaired uterine clearance. Alternatively, pentoxyfilline (7.5 mg/kg, PO, every 12 hours) can be used as an anti-endotoxic drug. This drug is most effective in combination with flunixin. Polymyxin B (6000 U/kg, IV, every 12 hours in 1 L of saline over 30–60 minutes) is another option for treatment of endotoxemia, as well as anti-endotoxin serum (1.5 ml/kg diluted 2-fold in balanced IV fluids) and hyperimmune plasma (2–10 ml/kg, IV). Preventive measures for laminitis include icing of feet, deep stall bedding, and soft rides. The mare may also need supportive therapy with intravenous fluids.

3. Results
In a retrospective study including 45 mares with metritis, the median day postpartum on presentation was 1 day (range, 0–6 days). Median mare age was 10 years (interquartile range, 8–12 years). On presentation, all mares had an enlarged, thin-walled, and atonic uterus on palpation per rectum, a moderate-to-large amount of intrauterine fluid on ultrasound per rectum, and a fetid, brownish-red-to-purulent vulvar discharge. Signs of sepsis included at least one of the following: elevated body temperature (>102°F), injected mucous membranes, anorexia, depression, leukocytosis (>12,000 leukocytes/μL), leukopenia (<6000 leukocytes/μL), or hyperfibrinogenemia (>400 mg/dL).

Historical data was available at the time of presentation to the hospital. However, detailed data were available for analysis from only 23 mares. In the population of 23 mares, the presenting complaint was retained fetal membranes (10/23 mares; 43.5%), abnormal vulvar discharge (7/23; 30.4%), agalactia (6/23; 26%), colic (5/23; 21.7%), fever (3/23; 13%), and postfoaling exam after placentitis (2/23; 8.7%). Some mares presented with multiple complaints. Predisposing factors included retained fetal membranes (10/23; 43.5%), placentitis (7/23; 30.4%) and dystocia (6/23; 26%). For the remaining 22 mares, partial history was available from the reports of the bacteriological tests.

Of the 45 mares, 17 had infections with a single organism (37.8%), whereas 28 mares had mixed infections (62.2%). Therefore, a total of 88 bacterial isolates were evaluated. Time to reporting was longer in mares with mixed growth (5 days; range, 1–18 days) than pure growth (3.2 days; range, 1–6 days) (T test; P = .01).

The most commonly isolated bacterium was *Escherichia coli* (30.7%). Mares with mixed growth...
most commonly grew a combination of Gram-negative and Gram-positive bacteria (19/29; 65.5%) while growth of all Gram-negative or all Gram-positive bacteria occurred in 17.2% (5/29) and 17.2% (5/29) of the mares, respectively. The most common combination was *Escherichia coli* and *Streptococcus zooepidemicus* (5/29; 17.9%) followed by *Escherichia coli* and *Klebsiella spp.* (2/29; 6.9%). When pure growth was obtained, Gram-negative bacteria (82.3%; 14/17) were more commonly implicated than Gram-positive bacteria (17.6%; 3/17) ($\chi^2; P = .01$). Anaerobic culture was performed in eight mares, with one mare (12.5%) yielding growth of *Prevotella oralis*.

A complete data set for all bacteria isolated is available.\(^7\) Sensitivity of Gram-negative isolates to aminoglycosides, cephalosporins, penicillins with beta lactamase inhibitors, tetracyclines, or quinolones ranged between 61.7% and 89%. The highest frequency of resistance to these antimicrobial groups was seen in *Enterobacter* spp., followed by *Klebsiella* spp. and *E. coli*. Only minocycline and imipenem were effective in vitro against 100% of Gram-negative isolates. Orbifloxacin was the only drug that was effective in vitro against 75% of *Enterobacter* spp. isolates. *Klebsiella* spp. and *E. coli* expressed the least resistance to amikacin, cephalosporins, quinolones, and chloramphenicol. Only 61.7% of Gram-negative bacteria were sensitive to gentamicin, and potentiated sulfonamides were among the least effective drugs against this bacterial group (48%).

The highest frequency of susceptibility among Gram-positive bacteria was seen to beta lactams, tetracyclines, potentiated sulfonamides, some macrolides, chloramphenicol, rifampin, and imipenem. Minocycline, amoxicillin with clavulanic acid, cefoxitin, and cefpodoxime were effective in vitro against 100% of Gram-positive isolates. *Streptococcus* was sensitive to most antimicrobials tested, with the least effective group being quinolones. Penicillin was effective against 76.5% of all Gram-positive bacteria.

The commonly recommended first choices for treatment of metritis were the least effective against the bacterial combinations isolated from these mares. Gentamicin and penicillin were an appropriate choice for 65.1% of the mares, and trimethoprim/sulfonamide was effective in only 48.8% of the mares. Better antimicrobial coverage was provided by minocycline (100%), penicillin with amikacin (90.7%), penicillin with enrofloxacin (81.4%), cefotiofur (79.1%), doxycycline (77.8%), and chloramphenicol (76.7%).

The prevalence of multidrug resistance (MDR) among all bacteria was 59.8%. The frequency of MDR was higher in Gram-negative (85.4%) than Gram-positive bacteria (23.5%) ($\chi^2; P < .001$). MDR was present in 100% of *Enterobacter* spp. and *Enterococcus* spp., 90% of *Klebsiella* spp., and 66.7% of other Gram-negative bacteria. No MDR *Streptococcus zooepidemicus* or *Streptococcus spp.* isolates were recovered from cases of equine metritis. MDR was particularly prevalent among mares that had been treated for placentitis with trimethoprim/sulfamethoxazole from the time of diagnosis until foaling. *Escherichia coli*, *Klebsiella spp.*, or *Enterobacter spp.* were isolated in pure growth within 24 hours post-partum from these mares, all of which showed MDR. Resistance to trimethoprim/sulfonamides or gentamicin/penicillin was present in 85.7% of these bacteria.

Treatment records were partially available from 17 of the mares. All mares were treated with once-daily uterine lavages and oxytocin. The most common initial antimicrobial choice was the combination of potassium penicillin with gentamicin (70.6%; 12/17) followed by trimethoprim/sulfamamide (17.6%; 3/17), enrofloxacin (5.9%; 1/17) and cefotiofur (5.9%; 1/17). In 29.4% (5/17) of these mares, the bacteria isolated were resistant to the initial antimicrobial choice. Hospitalization time did not differ between mares growing bacteria sensitive (6.1 ± 1 days) or resistant (8.2 ± 2 days) to the selected antibiotics (t-test; $P = .312$). Mares in both groups were hospitalized for a range of 1 to 14 days.

Anti-inflammatory and anti-endotoxic treatment included flunixin meglumine (53%; 9/17 mares), phenylbutazone (11.8%; 2/17), pentoxifylline (47%; 8/17), polymyxin B (11.8%; 2/17), and IV fluids (11.8%; 2/17). Hospitalization time did not differ ($P > .05$) between mares treated with these drugs or not (Table 1). In addition, 35% (6/17) mares required treatment with domperidone (1.1 mg/kg PO every 12 hours) to stimulate lactation due to a/hypogalactia.

Five of the mares (29.4%; 5/17) had systemic signs of endotoxemia or septicemia on presentation, two of which developed laminitis during the course of treatment. One of these mares was euthanized, while the rest recovered and were discharged from the hospital. None of the mares that grew bacteria sensitive to the initial antibiotic selection developed systemic complications after initiation of treatment. However, one of the mares that grew bacteria resistant to the antibiotics used (20%; 1/5) developed endotoxemia.

By the time culture results were reported, most mares had recovered clinically. Mares growing bacteria resistant to the initial antibiotic choice were discharged with instructions to continue anti-

### Table 1. Days of Hospitalization (Mean ± SEM) in Mares According to Treatment

<table>
<thead>
<tr>
<th>Treated</th>
<th>Flunixin</th>
<th>Meglumine</th>
<th>Pentoxifylline</th>
<th>Polymyxin B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>7.8 ± 1.4</td>
<td>8.5 ± 1.4</td>
<td>10 ± 4</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>5.5 ± 0.8</td>
<td>5.1 ± 0.9</td>
<td>6.2 ± 0.8</td>
<td></td>
</tr>
</tbody>
</table>
4. Discussion

Metritis is a complex, life-threatening disease. Rapid initiation of treatment is essential to preserve the mare’s life. Initial therapies are directed at reducing microbial load through uterine lavage, ebolic therapy, and administration of appropriate antimicrobials. It is always recommended to select antimicrobials based on diagnostic test results. However, the average time to reporting in this study was 4 days, with a maximum of 6 days in mares with pure growth and 18 days in mares with mixed growth due to standard operating procedures of the Bacteriology Laboratory. The extended turn-around times associated with these tests, and the high risk for life-threatening complications make empirical initiation of antibiotic therapy a necessity.

A higher prevalence of mixed than single infections was confirmed, with combinations of Gram positive and Gram negative bacteria being most common. Therefore, antimicrobials should be initially selected to provide broad-spectrum coverage. The most commonly used broad-spectrum combination used to treat metritis is penicillin with gentamicin, or trimethoprim/sulfonamides. However, both options were the least effective against the bacterial combinations isolated from the mares in this study. A better option may be the combination of penicillin with amikacin or with enrofloxacin. Alternatively, minocycline, doxycycline, cefitofur, and chloramphenicol may be appropriate options for oral and/or monodrug therapy.

Gram-negative bacteria and Enterococci were often associated with resistance to frequently used antimicrobials. Multidrug resistance was common, especially among Gram-negative bacteria. While complete medical records were not available from all mares, the information revealed interesting trends in antimicrobial resistance patterns. Thirty percent of the mares from which historical data were available had a history of placenta. All these mares were treated with trimethoprim/sulfamethoxazole from the time of diagnosis until foaling. Escherichia coli, Klebsiella spp., or Enterobacter spp. were isolated in pure growth within 24 hours postpartum, all of which showed MDR. Therefore, bacterial culture and susceptibility tests are strongly recommended in all postpartum mares with a history of placenta to select appropriate treatment.

While retained fetal membranes and abnormal vulvar discharge were common complaints, it was also of interest that agalactia and colic were conditions of mares that developed metritis. Even though the abnormal uterine contents and signs of sepsis were also present in these mares, they were overlooked by owners or referring veterinarians. The agalactia or colic could have been a sequell of metritis-associated endotoxemia or septicemia. This stresses the importance of performing a complete physical and gynecological examination in all mares presenting with postpartum disease.

While empiric therapy is generally based on expected pathogens, appropriateness of the antimicrobial drug and its dose, route, and frequency of administration in cases of equine metritis should always be supported by diagnostic testing, based on minimum inhibitory concentration (MIC) and known drug concentration achieved in the endometrium and in plasma. A bacterial culture and susceptibility test should be performed to guide antimicrobial choice and to monitor for the development of antimicrobial resistance in equine uterine pathogens.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References

How to Utilize Controlled Manual Removal of Fetal Membranes in Mares

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The described method of controlled, manual removal of fetal membranes provides a safe, efficient treatment approach for managing fetal membranes in high-risk and normal-foaling mares. Authors’ addresses: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32611 (Burden, Macpherson, Pozor, Randell, Hayna); Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Georgia, Athens, GA 30602 (Giguère); e-mail: macphersonm@ufl.edu. *Corresponding author; †presenting author. © 2018 AAEP.

1. Introduction
Retained fetal membranes (RFMs) represent one of the more common postpartum problems in mares. While the overall incidence is low (2–10.6% of mares),1,2 the consequences, if left unattended, can be severe. Several factors are associated with a higher occurrence of RFM including mare age, previous RFM, breed, and peripartum complications such as abortion, dystocia, placentitis, prolonged gestation, and hydropic conditions.1,3,4,5

The cause of RFM in mares is not well defined and is likely multifactorial. It is hypothesized that a multitude of impaired physiologic changes are involved, leading to an abnormal release of the microvilli from the endometrial crypts in susceptible mares.2 Uterine inertia due to hormonal imbalances at the time of parturition along with specific placental characteristics may account for the higher incidence of retention.6 Allantochorion thickness, microvilli length, and degree of attachment at parturition along with an increased folding pattern of the non-gravid horn are potential factors in increased membrane retention.2 Fibrosis and adhesion formation have been reported in both the microcotelydons and stromal connective tissue in heavy draft breeds while low serum calcium concentrations have been directly linked to incidence of RFM in Friesian mares.7,8

No matter the cause, RFM can lead to life-threatening sequelae in mares such as metritis, sepsis, and laminitis.5,9 Prompt medical management is warranted if membranes are retained longer than 3 hours postpartum. Proactive management of membrane removal (prior to 3 hours) may prove beneficial for mares with placentitis, abortion, or dystocia and for intensely managed broodmare operations or mares at distant locations.

A variety of methods for retained membrane removal in the mare have been described.1,3,8,10,11
The most common method to aid in fetal membrane removal is administration of oxytocin in the early postpartum period. Oxytocin is administered at a dose of 10 to 20 IU, IV or IM, and repeated every 2 to 4 hours for the first 6 hours post-foaling or until complete expulsion of the fetal membranes is achieved.12,13 Alternatively, 60 to 100 IU can be mixed in 1 to 2 L of lactated Ringer’s solution or 0.9% saline solution and administered slowly (30–60 minutes), IV.2 Uterine lavage is often combined with oxytocin administration to prompt membrane expulsion. When the membranes are intact, the chorioallantois can be distended with dilute betadine solution or 0.9% saline (Burns technique), which often will stimulate release of microcotyledons from the endometrium.14 More recently, a technique using catheterization of an exposed umbilical vessel to allow distension of membrane vasculature and detachment of the chorioallantois from the endometrium has been described.15

Controlled, manual removal of fetal membranes is a method of membrane removal that has been employed for many years using a variety of approaches.3,14,16–18 Potential advantages of this procedure are below:

- Rapid removal of membranes in the immediate postpartum period, thus reducing the risk of sequelae such as metritis or laminitis if membranes are retained
- Membrane assessment to facilitate early medical treatment of either the mare or foal
- Efficiency and peace of mind (for the veterinarian)

Potential risks of controlled membrane removal are below:

- Increasing the risk of postpartum hemorrhage after separating the membranes from the endometrium
- Tearing the membranes, thus inducing RFM
- Retention of microvilli after removal, thus increasing the risk of metritis
- Uterine horn eversion/intussusception or prolapse

Techniques that have been described for manual fetal membrane removal include grasping the externalized free portion of the membranes and applying controlled traction,3,19 placing a hand between the endometrium and chorion to separate the attached membranes, twisting of the allantochorionic membrane into a tight cord,7 and placing a wooden ring between the chorion and endometrium and advancing the ring to separate the membranes from the endometrium.3 The goal of this paper is to describe a practical, safe method for controlled manual removal of fetal membranes. Data from an experimental model of placentitis are reported to illustrate complications that may occur when using this procedure in abnormal (placentitis) vs normal-foaling mares.

2. Materials and Methods

A total of 18 pony mares (139–487 kg) were enrolled in a trial studying equine placentitis. The placentitis study was approved by the Institutional Animal Care and Use Committee of the University of Florida (#20138128). Placentitis was induced in 12 mares using a direct inoculation of Streptococcus equi subsp. zooepidemicus on the chorioallantois. Six additional control mares were not infected and allowed to foal normally. All deliveries were attended and assisted. Immediately after foaling, the mare and foal were allowed to bond (if the foal was born alive) for a short period before manual membrane removal was attempted.

Membrane removal was performed with the mare standing or in sternal recumbency. Sternal recumbency was preferred because it eliminated the dependent weight of the placenta while performing the procedure. The mare’s tail was wrapped and pulled laterally and the perineal area was cleansed. Wearing a sterile examination glove, the veterinarian determined the degree of fetal membrane attachment to the endometrium through digital examination of the reproductive tract. Most often, the gravid horn was detached and free within the uterus while the nongravid horn remained attached to the endometrium. With a scissors-like action, two fingers were used to bluntly “dissect” the most caudally attached portion of the chorioallantois from the endometrium (uterine body and base of one or both horns) (Fig. 1). With the base of the horns free from the endometrium, the membranes of the attached horn were encircled using the thumb and forefinger (Fig. 2). This “ring” of fingers was used in a gentle manner to move cranially up and back on the attached membranes to evenly separate the chorioallantois from the endometrium. Controlled pressure and digital separation were repeatedly applied in a cranial direction toward the tip of the uterine horn. As membranes were separated from the endometrium, the “free” portion was exteriorized.
and transferred to the external hand (Fig. 3). The external hand was used to relieve tension from the weight of the attached membranes to reduce the probability of membrane tearing or uterine horn eversion. This step was especially important for abnormally heavy membranes from mares with placentitis. Gentle detachment of the chorionallantois from the endometrium was continued as long as separation was easily performed. When membranes did not detach readily from the endometrium, the procedure was discontinued until re-evaluation approximately 30 minutes later. Manual detachment was performed until the tip of the placental horn was released and the membranes exteriorized. The fetal membranes were examined for completeness and abnormalities after removal. The mare’s reproductive tract was evaluated immediately after membrane removal using digital examination to identify uterine positional abnormalities or placental complications (uterine horn eversion, uterine prolapse, placental tag retention). Displaced uterine horns were replaced manually followed by uterine lavage and oxytocin. All infected mares or mares with RFM (≥ 3 hours after foal delivery) underwent uterine lavage therapy and were administered therapeutic doses of oxytocin (ecbolic), antimicrobials (trimethoprim sulfadiazine, ceftiofur sodium, gentamicin), and flunixin meglumine or firocoxib as needed. Mares remained under direct observation for 24 hours after placental removal for signs of excessive discomfort.

The association between manual placental removal and complications for mares was examined using Fisher’s Exact Test. Differences were considered significant when \( P < .05 \).

3. Results
The data regarding incidence of complications after manual removal or spontaneous expulsion of fetal membranes (normal-foaling mares and mares with induced placentitis) are presented in Table 1. Five mares delivered placentas (spontaneously) before manual intervention could be performed. One mare was excluded from the data set because fetal membranes were evacuated immediately after dystocia and controlled vaginal delivery under general anesthesia.

Differences were not detected \( (P > .05) \) for incidence of uterine complications (horn eversion/prolapse) after manual placental removal vs spontaneous placental expulsion in either mares with placentitis or normal-foaling mares. Overall, fetal membranes were manually removed from 12 of 17 mares. Membranes were removed without complications in 9 of 12 mares (9/12; 75%). Three mares whose membranes were removed

| Table 1. Incidence of Complications after Manual Membrane Removal Versus Spontaneous Fetal Membrane Expulsion in Normal-Foaling Mares and Mares with Induced Placentitis |
|---------------------------------|-----------------|-----------------|-----------------|-----------------|
|                                | Placentitis (n = 11) | Normal (n = 6)  |
|                                | Removed | Spontaneous | Removed | Spontaneous |
| No complications               | 5       | 0             | 4       | 1             |
| Complications                  | 3       | 3             | 0       | 1             |
(3/12; 25%) suffered complications (uterine horn eversion [n = 2]; uterine prolapse [n = 1]). Five mares spontaneously expelled fetal membranes after delivery of the foal. Four of those five mares (4/5; 80%) suffered complications (two mares with uterine horn inversion, one mare with uterine prolapse, one mare retained the tip of the nongravid horn). The majority of mares suffering complications (6/17; 35%), independent of spontaneous expulsion or manual membrane removal, had placentitis and abnormally heavy fetal membranes (> 11% of foal body weight). Membranes from mares with placentitis weighed 20.1 ± 0.04% (mean ± SD) of foal body weight (kg) compared with membranes from normal-foaling mares (10.6 ± 0.04%).

4. Discussion

Manual removal of fetal membranes is a commonly used technique but has varying degrees of acceptability among equine veterinarians. Proponents of manual membrane removal cite advantages of rapid expulsion, thorough examination of membranes by a veterinarian, and reduced risk of retained membranes causing secondary complications. Potential risks of manual membrane removal are tearing and retention of fetal membranes, hemorrhage, and uterine horn eversion/uterine prolapse. The circumstances relevant to the mare (normal vs high-risk pregnancy) and veterinarian (experience, access to the mare, breeding schedule) likely dictate the right decision for each mare. Essential to the decision-making process is a thorough knowledge of how to safely perform manual membrane removal to ensure the health of the mare. Risk factors that may negatively impact a mare if the membranes are not promptly removed include complications associated with fetal membranes. Specifically, mares with induced placentitis included in this data analysis had abnormally heavy fetal membranes (20% of foal body weight) when compared with fetal membranes from normal, uninfected mares (11% foal body weight). Uterine horn eversion/prolapse or RFMs occurred primarily in mares with placentitis, who delivered fetal membranes at twice the normal weight. This finding suggests a relationship between fetal membrane weight and uterine horn abnormalities postpartum. In fact, controlled manual removal of membranes from mares with placentitis may be advantageous for these high-risk mares. Rapid removal of the (heavy) membranes would reduce the tension on the uterine horn, thus reducing the risk of membrane tearing, uterine eversion, or prolapse. Prompt evaluation of the reproductive tract both during and after manual membrane removal would aid in rapid diagnosis, and correction, of uterine horn abnormalities. Finally, removal of membranes simplifies postpartum treatments such as uterine lavage.

The debate remains regarding the usefulness of controlled manual removal in normal-foaling mares. The advantages of time-saving and proper evaluation for the attending veterinarian are clear. The method is quick and relatively easily performed in experienced hands. There is no need for specialized equipment during the procedure, and it can be easily performed on the farm or in a clinical setting. The described method also allows the veterinarian to apply mild and uniform pressure to the full circumference of the membrane at its attachment (typically nongravid horn) which allows “real-time,” controlled assessment of membrane release from the endometrium.

Important to the discussion is the long-term effect of manual membrane removal on future fertility of mares. Fertility data from mares in this study are confounded by factors such as induced placentitis. Fertility after manual placental removal, using a variation of this technique, has been investigated in one small study of normal-foaling mares. Twelve mares underwent manual removal of fetal membranes and 12 mares were allowed to spontaneously expel membranes. Manual removal was achieved by grasping the distal placenta outside of the vulva with additional traction placed on the fetal membranes immediately inside the vulva. First cycle and seasonal pregnancy rates were similar for the two populations of mares. Secondary complications were not reported for either group. While these data cannot be extrapolated for all populations, the rapid return to fertility after membrane removal is encouraging. Further, anecdotal experience (Burden, personal communication) regarding manual fetal membrane removal (as described here) used in Thoroughbreds and other light breed mares support rapid return to fertility after the procedure is performed.

5. Summary

Management of RFMs is a priority for the health of affected mares. Oxytocin administration is often the first line of therapy for management of RFM. Controlled manual removal of fetal membranes allowed for rapid membrane removal with relatively low risk to both normal foaling and high-risk mares in this study. Abnormally heavy placentas, with or without manual removal, increased the risk for uterine complications after foaling. Membrane removal facilitated concurrent evaluation of the postpartum uterus, thus prompting rapid resolution of significant postpartum complications such as uterine horn eversion or prolapse. Controlled fetal membrane removal is a practical, efficient tool that, when performed correctly, can improve the health of postpartum mares.

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out which the present study could not have been completed. Aurora Pharmaceutical generously provided Equisul-SDT for treatment of postpartum mares. Finally, student workers from the University of Florida were essential to the healthcare of both mares and foals in this project.

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References

Pregnancy Rates After Laparoscopic Application of Prostaglandin E\(_2\) or Hysteroscopic Hydrotubation of the Uterine Tubes

Stephanie R. Walbornn, DVM, DACT*; Maria R. Schnobrich, VMD, DACT; Etta A. Bradecamp, DVM, DACT, DABVP; Charles F. Scoggin, DVM, MS, DACT; and J. Brett Woodie, DVM, MS, DACVS

Occlusion of the uterine tube may cause infertility in the mare. Pregnancy rates were evaluated after either laparoscopic application of prostaglandin E\(_2\) to the uterine tubes or hysteroscopic hydrotubation of the uterine tubes. Pregnancy rates were similar between both procedures allowing the practitioner to elect either procedure to treat this condition. Authors’ address: LeBlanc Reproductive Center (Schnobrich, Scoggin, Bradecamp), Rood and Riddle Equine Hospital (Woodie), 2150 Georgetown Rd., Lexington, KY 40511; Rood and Riddle Equine Hospital in Wellington, 5320 South Shore Blvd., Wellington, FL, 33449 (Walborn); e-mail: swalbornn@gmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Uterine tube pathologies have been identified in the mare, although they are relatively rare. Two treatment options for uterine tube occlusion include laparoscopic application of prostaglandin E\(_2\) (PGE\(_2\)) to the uterine tubes and hysteroscopic hydrotubation of the uterine tubes. These techniques have successfully established pregnancies in mares that have a history of unexplained infertility.

2. Materials and Methods

Medical records of 69 broodmares (age range; 4–22 years) that had undergone either procedure were reviewed. Mares were included if they had been barren for a year and no cause of infertility was identified prior to the performance of either procedure. Pregnancy rates at around 14 days were compared using Pearson’s \(\chi^2\) test for independence \((P < .05)\).

3. Results and Discussion

Twenty mares underwent laparoscopic application of PGE\(_2\) to the uterine tubes and 13/20 mares became pregnant (65% pregnancy rate). Forty-nine mares underwent hysteroscopic hydrotubation of the uterine tubes, and 35/49 mares became pregnant following the procedure (71% pregnancy rate). There was no significant difference in pregnancy rates between the two procedures analyzed \((P > .05; P = 0.59)\).

Laparoscopic application of PGE\(_2\) to the uterine tubes or hysteroscopic hydrotubation of the uterine tubes can be utilized successfully to treat mares with unexplained infertility from presumed uterine tube obstruction.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.

Research Abstract—for more information, contact the corresponding author
IUD Modulation of the Reproductive Cycle

Carlos Gradil, DVM, MS, PhD, DACT*; and Allison Schwarz, BS

1. Introduction
Mares in estrus can behave in ways that can interfere with handling and competition. The objective of the present study was to evaluate a novel intrauterine device (IUD) for its effect on estrus behavior suppression.

2. Materials and Methods
The self-assembling magnetic IUD consists of 3 magnetic ovals (22.5 g) each with a magnetic core and coated with a polymer. Each is inserted independently from the other. In mares, the device can be inserted at any stage of the estrous cycle without the need for multiple exams. Once inside the uterus, these magnetic ovals will self assemble and adapt the lower energy “ring” conformation. Shatter proof grade material is used to assure safety for long-term use. The IUDs are inserted and retrieved using an applicator and magnetic retriever.

3. Results
Experiment 1. Fifteen mares: IUDs were inserted post-ovulation. The IUD extended the length of diestrus: 73.4 ± 2.3 days (mean ± SE, range 20–155 days). Endometrial integrity was not significantly affected by the device. Experiment 2. Fifteen mares: IUDs were inserted regardless of the stage of the estrous cycle. Length of diestrus: 40.4 ± 1.0 days (mean ± SE, range 7–98 days) in mares that were in diestrus and 36.4 ± 1.1 days (mean ± SE, range 15–67 days) for mares in estrus, at time of insertion. The presence of the IUD was monitored by transrectal ultrasound and external metal detector. Progesterone was assayed to monitor corpus luteum lifespan. Control mares: 8.

4. Conclusion
The IUD cumulative retention was 294 Mare-21-day cycles, with 100% retention. No device was lost.

Acknowledgments
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Conflict of Interest
The Authors have no conflicts of interest.
Genetic Risk for Ocular Squamous Cell Carcinoma in Belgian Horses

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A genetic risk factor for ocular squamous cell carcinoma in Belgian horses has been identified. Belgian horses homozygous for a variant in damage-specific DNA binding protein 2 (DDB2 c.1013C>T) have a 4.0 times greater risk of developing this cancer than Belgian horses with genotypes C/C or C/T. A DNA test is available. Authors’ addresses: Veterinary Medical Teaching Hospital, Veterinary Genetics Laboratory, (Knickelbein, Singer-Berk, Bellone), Department of Surgical and Radiological Sciences (Lassaline), Department of Pathology, Microbiology, and Immunology (Reilly), Department of Population Health and Reproduction (Bellone), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; New England Equine Medical & Surgical Center, PLLC, Dover, NH 03820 (Clode); Blue Pearl Specialty and Emergency Pet Hospital, Tampa, FL 33614 (Miller Michau); Current address for Reilly: Insight Veterinary Specialty Pathology, Austin, TX 78752; e-mail: keknickelbein@gmail.com. © 2018 AAEP.

1. Introduction
Squamous cell carcinoma (SCC) is the most common cancer to affect the equine eye. Belgian horses are over-represented for the disease. Chestnut coat color may increase risk. A recessive risk factor in DDB2 c.1013C>T has been established for ocular SCC in Haflinger horses. The Belgian breed was demonstrated to possess the variant allele at a similar frequency. This study aims to determine the association between the DDB2 variant and ocular SCC in Belgian horses.

2. Materials and Methods
Genomic DNA was isolated from blood, hair, or formalin-fixed, paraffin-embedded tissue from 23 histologically confirmed ocular SCC-affected Belgian horses and 18 unaffected Belgian horses (controls). Genotyping for the DDB2 variant and coat color loci was performed. Association testing was performed and relative risk calculated.

3. Results
Homozygosity for the DDB2 variant was strongly associated with ocular SCC (P = 1.9 × 10−6). Nearly 74% (73.9%) of cases were homozygous for the DDB2 variant and relative risk was calculated as 4.0 (P = 1.0 × 10−4). No significant association between disease and coat color loci was found.

4. Discussion
The DDB2 variant is an inherited risk factor for ocular SCC in horses, which impacts the Belgian and Haflinger breeds. Genetic testing should be implemented to inform breeding and clinical management decisions.

Research Abstract—for more information, contact the corresponding author

NOTES
Acknowledgments
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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Dr. Rebecca Bellone serves as the Director of the UC Davis Veterinary Genetics Laboratory. This laboratory offers genetic diagnostic testing in horses and other species.

The other Authors have no conflicts of interest.
How to Use the Madigan Foal Squeeze Technique for Treatment of Maladjustment Syndrome and for Performing Minor Procedures and Administration of Plasma in Healthy Neonatal Foals

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1. Introduction
Neonatal foals are sensitive to squeeze pressure and often buckle or collapse when held tightly, a phenomenon known as the flopping reaction. A rope squeeze method has been described that creates recumbence and a sleep-like state with some reduction in pain responses. The authors use this method as an aid in the treatment of foals with maladjustment syndrome, which is described elsewhere. The squeeze procedure is also used routinely in foals less than 3 days of age for administration of plasma while the foal is recumbent and in the stall adjacent to the mare, and performance of minor procedures and ultrasound exams. The advantages are that the foal does not have to be heavily restrained or be fearful with the first encounters with a veterinarian.

2. Materials and Methods
The step-by-step procedure for performing the squeeze method is detailed below.

Precautions
Contraindications for use of the squeeze are rib fractures, respiratory distress, foals in septic shock, severe prematurity with floppy chests, severe neuromuscular disease compromising normal breathing, and congenital anomalies.

Only skilled clinicians familiar with neonatal foal and maternal interactions should perform
this procedure. The mare should be allowed to stand close to the foal and most mares seem to know the foal is asleep and they stand quietly. Some mares are aggressive postbirth and the degree of restraint of the mare should be a judgment call.

The duration of the squeeze should be limited to 20–30 minutes and the foal’s respiration, heart rate, and mucous membrane color monitored.

The foal is in slow wave sleep and not anesthetized and may arouse during the squeeze procedure and could kick. Always position yourself behind the back of the foal and away from the limbs.

The squeeze method works best for foals from newborn to 3 days of age. After 3 days, the squeeze method is inconsistent in producing recumbence and sleep.

Practice Tips for Use of the Squeeze Method in Maladjusted Foals

Apply the rope system and allow the foal to sleep for 20 minutes, with a soft towel covering the foals’ eyes. Have the mare stand immediately adjacent to the foal so she does not whinny or arouse the foal. Keep a constant pressure on the rope and if the foal moves, add a bit of pressure and allow the foal to resume sleeping. Upon reaching the 20-minute time period, remove the rope but allow the foal to sleep as long as it wants. Do not stimulate the foal to stand if it is laying quietly. When the foal attempts to stand, stimulate it on its back with a pinch of the skin to mimic when mares often nip the back of the foal. Allow the foal to wander toward the mares' udder and observe for nursing. In the authors' experience, only one foal had milk coming out of the nose while nursing. Most foals latch on to the mare nipple with a coordinated tongue curl and suckle.

Note the foal’s ear position and alertness postsqueeze and observe over the next hour for any change. If the foal initially appears more alert but does not quite get to the udder for a complete suckle of the mare, repeat the foal squeeze at 2–4-hour intervals until arousal is maintained. The authors have squeezed some foals every 4 hours over a 24-hour period.

The squeeze method is not contraindicated in a seizing foal and may lessen the seizure in some foals. Appropriate management of seizures should be carried out and the squeeze procedure used in refractive cases. The following explains step-by-step how to perform the squeeze procedure.

Step-by-Step Instructions for Using the Madigan Squeeze Method in Neonatal Foals

1. Tie a bowline knot and make a fixed loop so that the rope will slide through like a honda on a lariat.
2. How to tie the bowline knot: http://www.animatedknots.com/bowline/.

Rope Placement

- Starting at the withers area, place the rope across the neck and between the front limbs and bring the end of the rope up to the withers area (see Step 1: Fig. 1).
- Thread the end of the rope through the loop at the end of the rope and snug the rope (see Step 2: Fig. 2).
- Pass the rope over the foal and make a half hitch and snug the rope just behind the elbow where a cinch would go on a saddle (see Step 3: Fig. 3).

Fig. 1. Step 1: Put the rope over the withers and between the front limbs.

Fig. 2. Step 2: Run the rope through the loop at the end of the rope and snug the rope.
Pass the rope over the foal’s ribcage again about 6 inches back from the first half hitch and snug it up (see Step 4: Fig. 4).

Have the assistant hold the foal and position yourself behind the foal and put pressure on the rope until the foal begins to lie down (see Step 5: Fig. 5).

**Squeezing**

- Keep the same pressure on the foal when it lies down and same pressure for the 20-minute duration of the squeeze (see Step 6: Fig. 6).
- Allow the mare to be standing close viewing the foal. They seem to know the foal is asleep and stand watch.
- Protect yourself from the foal kicking or moving its head during this time. Some foals seem to move once or twice during the 20 minutes of squeeze. The amount of pressure is just the amount needed to have the foal lie down.
- When you pull on the rope and the foal begins to lie down, keep that same pressure on for 20 minutes. Using a luggage scale, it should register at about 10–20 lbs of pressure.
- At the end of the 20-minute squeeze, release pressure on the rope and allow the foal to stay down or get up as it chooses.
- Slowly move the rope away from the foal. Do not force it to get up. Let the foal sleep more if it wants.
- When the foal gets up, allow it to do whatever it wants and observe. Do not attempt to assist nursing or push to the mare.

3. Results

The squeeze procedure has been used for plasma administration for *Rhodococcus equi* prevention in over 200 Thoroughbred foals on one farm over a
The foals are treated within 24 hours of birth. In a study of use of the squeeze method in maladjusted foals, more than 30% of foals nursed within 1 hour. With conventional treatment, only 4% of foals nursed within 1 hour.2

Some foals with maladjustment syndrome that have been fully recumbent when the rope system has been applied have responded by standing and nursing. The safety of the procedure has been described, measuring heart rate, respiratory rate, venous blood gas and pH, lactate, and routine chemistries in experimental foals.1 Brain wave results indicate that during the squeeze procedure, the foal enters slow wave sleep.

The age of foals seems to be a factor in response to the squeeze. Foals less than 3 days of age are more consistent in their response. In slightly older healthy foals where the foal needs to be restrained, the authors have used low dose of xylazine (25–50 mg to an average size foal) prior to the squeeze procedure. The authors have one farm that has used that method in foals up to 7 days of age in over 50 foals without complication. It should be noted that xylazine is contraindicated in very ill and cardiovascularly compromised foals and may induce hypovolemic shock.

Acknowledgments

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Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA. The study was reviewed and approved by an Animal Care and Use protocol.

Conflict of Interest

The Authors have no conflicts of interest.

References


A Missense Mutation in MYH1 Is Associated with Susceptibility to Immune-Mediated Myositis in Quarter Horses

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Immune-mediated myositis (IMM) causes rapid-onset muscle atrophy in Quarter Horse–related breeds. An autosomal-dominant mutation in the gene encoding type 2X myosin has been found to cause IMM and a genetic test is available for diagnosis and screening of breeding animals through the Veterinary Genetics Laboratory at the University of California–Davis. Authors’ addresses: Department of Large Animal Clinical Sciences, Michigan State University, East Lansing MI 48824 (Valberg, Perumbakkam, Williams, Gardner); Department of Population Health and Reproduction, University of California–Davis, Davis, CA 95616 (Finno, Gianino, Bordbari, Burns, Peng); Department of Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, St. Paul, MN 55108 (Durward-Akhurst); e-mail: valbergs@msu.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

The purpose of this study was to identify a putative genetic mutation associated with equine immune-mediated myositis (IMM) that is characterized by rapid-onset muscle atrophy and lymphocytic infiltration of myofibers.

2. Materials and Methods

A genome-wide association study was performed on 36 IMM Quarter Horses (QHs) and 54 breed-matched unaffected QHs from the same environment using the Equine SNP50 and SNP70 genotyping arrays and whole-genome sequencing was performed on 4 IMM and 4 control QHs.

3. Results

A mixed-model analysis identified nine single nucleotide polymorphisms (SNPs) within a ~2.87 Mb region on chr11 that were significantly ($P_{\text{unadjusted}} < 1.4 \times 10^{-6}$) associated with the IMM phenotype. Whole-genome sequencing identified a single segregating nonsynonymous E321G mutation in type 2X myosin (MYH1) encoding myosin heavy-chain 2X.

Research Abstract—for more information, contact the corresponding author

NOTES
Genotyping of additional 35 IMM and 22 unaffected QHs confirmed an association \( (P = 2.9 \times 10^{-5}) \) and the putative mutation was absent in 175 horses from 21 non-QH breeds. Protein modeling identified 14 residues affected by the mutation, which significantly decreased stability.

4. Conclusions
The authors conclude that a mutation in \( MYH1 \) is highly associated with susceptibility to the IMM phenotype in QH-related breeds. This is the first report of a mutation in \( MYH1 \) and the first link between a skeletal muscle myosin mutation and autoimmune disease.\(^1\)

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Dr. Valberg is one of the owners of the patent for the PSSM genetic test and receives sales income from its use. Her financial interest has been reviewed and managed by the University in accordance with its conflict of interest policies.

Michigan State University and the University of California, Davis have applied for a patent for the E321G MYH1 genetic mutation test.

References
EHV-1 Vaginal Shedding Occurs in Healthy Broodmares

Carina Joppe Cooper, DVM*; Luis Guillermo Arroyo, LMV, DVSc, PhD, DACVIM; and Brandon Lillie, DVM, PhD, DACVP

EHV-1 can be shed from the vagina as well as the nasal mucosa in healthy broodmares, independent of viremia. The vagina should be investigated as a potential source of infection or viral spread during disease. Authors’ addresses: Department of Pathobiology (Cooper, Lillie), Department of Clinical Studies (Arroyo), Ontario Veterinary College–Guelph, 50 Stone Rd. E., Guelph, ON, Canada, N1G 2W1; e-mail: carinacooperdvm@gmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Equine herpesvirus-1 (EHV-1) is known to cause illness in all ages of equids, from abortion and perinatal death to respiratory and neurologic disease in adults with a significant economic impact, especially on the breeding industry. The herpesvirus causes latent infections, but vaginal viral shedding in otherwise-healthy horses has not been investigated. Healthy broodmares have been implicated in exposing naïve foals; therefore, subclinical shedding was suspected.

2. Materials and Methods
A total of 330 healthy broodmares of various breeds were enrolled across Southern Ontario, and sampled in December 2016 and February 2017. EHV-1 DNA was isolated from blood (buffy coat) as well as nasal and vaginal swabs. Digital droplet PCR specific to the glycoprotein B (gB) gene of EHV-1 was used to identify samples with viral particles.

3. Results
EHV-1 DNA was identified in 54.2% of horses enrolled, with active shedding identified in 38.4% through the vagina (23%) or nasal mucosa (13%).

4. Discussion
Vaginal viral shedding of EHV-1 has not been previously described. EHV-1 DNA was identified in the majority of horses enrolled, despite no signs of infection. Vaginal shedding should be further investigated during clinical disease to determine if it provides a significant source of viral contamination, and/or is a useful method for EHV-1 detection.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors have no conflicts of interest.
Industry Standards for Sport Horse Pre-Purchase Examination in the United States

Melissa A. Welker, DVM

1. Introduction
The equine pre-purchase exam has evolved a great deal in recent years. As technology advances, so does the level of complication these exams often entail. The value of sport horses have increased dramatically in the last decade, creating a new sense of pressures on the buyer, seller, and veterinary practitioner asked to perform a pre-purchase exam. At a high level of sport, these exams involve not only an in-depth clinical exam, but also imaging and videography to document findings. Additionally, background research into the horse’s show record and management history have also become significant factors influencing the overall outcome of these transactions. The following sections are structured to represent the flow of a typical pre-purchase exam conducted in the United States based on current industry standards on high-level sport horses. Although there will be variations depending on client’s expectations, this is a representation of a typical exam conducted in the United States. The implementation of a thorough system in conjunction with clear client communication will help ensure that the buyer’s interests are well represented and that the veterinary practitioner has provided as much information as possible to help them make the best decision.

2. Materials and Methods
When beginning the pre-purchase exam of the sport horse, the first piece of valuable information is to know what are the expectations of the buyer you will be representing. If it is not a regular client that you are familiar with, it is useful to understand what they hope to use the horse for and what their long-term goals are for the horse. Start the exam by knowing this and keep this in mind when forming an opinion of the horse.

The author prefers to evaluate the horse in the stall at the beginning of the exam. This provides a few minutes to interpret the horse’s behavior in the stable as well as the ability to perform a physical exam in a more peaceful environment. At this point, conduct the auscultations of the heart, lungs, and abdomen; check for surgical scars of the abdomen, throat latch, and palmar pasterns; and take the horse’s temperature. This is generally a good time to scan the horse for a microchip and check the International Federation for Equestrian Sports (FEI) Database or breed passport against its’ markings. While checking the passport, match the age reported in the passport to the findings while aging the teeth of the horse. The ophthalmic exam is done in the darkest setting possible, so this may vary between the stall and the aisleway.
The author prefers to examine the horse completely before drawing blood as not to upset the horse. The blood samples are collected for complete blood cell count, serum chemistry, enzyme immunoassay, and a drug/medication screen.

Next, examine the horse starting at the mouth, working your way down the front limbs, and then across the back and pelvis and continuing down the hind limbs. It is useful to evaluate the horse in the aisleway in order to visualize the hooves very well and the horse's muscle tone and conformation. It is important to note excessive effusion in the joints and digital flexor tendon sheaths and the quality of hoof horn and remark on how the horse is currently shod. Palpation of the soft tissue structures of all four limbs is vital to an exam and helps with interpretation of ultrasonography findings later in the exam. This segment of the exam ends with hoof testing all four feet and recording the horse's reaction.

Speak to the owner, trainer, or person who has been responsible for the horse's care while in the current program. Ask them direct questions regarding the history of the horse and document direct communications to them and record their responses. In recent years, it has become routine to ask the sellers to disclose the records of the horse for review by the veterinarian performing the pre-purchase exam. As a result, it is helpful to have two forms of history.

At this juncture, begin the dynamic phase of the exam. Ask the handler to walk the horse away and back, noting the manner in which the horse uses his head, neck, and back. This is also a good opportunity to assess muscle symmetry and an overall impression of health and conformation. Next, spin the horse in a small circle. The author prefers to personally handle the horse because while assessing coordination, much information is available by observing the way the horse reacts when asked to bend tightly through the cervical column. Many horses with a rigid neck will not willingly bend well in this small of a circle and will put a great deal of resistance on the lead in a particular direction. Ask the horse to back a few steps. In the author’s experience, this tests not only coordination, but also temperament of the horse and potentially the presence of cervical pain. A baseline exam of the horse trotting in a straight line is performed before beginning the flexions tests.

The flexion tests are the next phase of the exam. The author most commonly do the flexions while examining the horse in hand on a hard surface. Break the flexions into each joint or region separately while alternating between each front and hind limb. The typical flow of the flexion tests include the following: carpus, fore fetlock, hind fetlock, hock, stifle extension, stifle cross over, and coffin joint. In the event there is evidence of a forelimb lameness, add upper limb flexions. The typical amount of time to hold a flexion is approximately 50 seconds. Following the flexion tests, lunge the horse without tack both on soft ground and firm ground if available. This is a prime opportunity to see how the horse will use his body posture to compensate for upper limb issues. Without the influence of the rider, the horse will exhibit various body postures while traveling in each gait to avoid discomfort. A great deal of information can be obtained by observing the direction the horse is leaning, head and neck posture, as well as resistance to travel one direction or another. Ask the handler to put the horse through the walk, trot, and canter both directions.

Next, have the handler tack the horse up, which the author prefers to watch. It is a good opportunity to access the horse’s temperament again and overall comfort once the saddle is being placed. An area of a lot of discussion, which is very important, is the under saddle exam. Seeing the horse doing its “job,” allows the practitioner to gain important information when weight is applied to the horse’s back. Many of the horse’s the author examines are acceptably sound in hand but significantly lame with a rider on their back. The horse is ridden in loose and connected frames while being evaluated at the walk, trot, and canter. Ask the rider to lengthen and shorten the stride at both the trot and canter. The flying lead changes are evaluated for how well they are executed and the horse’s demeanor when being asked to perform them. After the canter, ask the rider to post on the incorrect diagonal to access hind limb lameness. Next, ask the rider to ride in a typical flat work frame for that particular horse. A more collected frame shows how willing the horse is to flex the neck, back, and load the hind limbs. A frame with less contact often enhances hind limb lameness due to lack of engagement of the horse’s core. Lastly, the horse is galloped around the arena to increase the heart rate for cardiac auscultation. It often proves difficult to find a suitable hard ground surface safe enough to ride the horse on, but when one is available, this is included in the exam. The author does not typically perform upper airway endoscopy unless an upper respiratory issue during the clinical exam is appreciated. At the conclusion of the under saddle exam, move on to the imaging portion of the pre-purchase exam.

3. Imaging
Standard imaging in the sport horse pre-purchase exam has also evolved a great deal in recent years. Standard radiographic series include 55–60 radiographs and includes the cervical and thoracic spines unless a client specifically declines these areas. The protocol includes dorsopalmar (DP) and lateral to medial of the front feet, 60 degree DP, and skyline of the navicular bone. The author routinely takes 60 degree oblique views of the navicular bone to obtain a better view of the edge of the navicular bone. All four fetlocks are imaged with four views,
including DP, lateral to medial, and dorsopalmar-lateral medial oblique (DPLMO) and dorsopalmar-medial lateral oblique (DPMLO). In the forelimb, the lateral to medial view is taken in a flexed position, and in the hind limbs, the author will typically take a standing view. The carpus is imaged with a DP and lateral to medial view unless there is clinical concern with the carpus. The hocks are four standard views, including DP, lateral to medial, DPLMO, and DPMLO. The stifle imaging consists of two views: 20 degree caudoproximal-cranialdistal, and caudolateral to cranialmedial 20 degree oblique.

The ultrasonographic exam is also a routine aspect of the sport horse pre-purchase exam. The author typically examines all four limbs as a survey with long axis measurements as standard and conduct cross-sectional area measurements if the structure being imaged is notably enlarged. These measurements are highly variable and should be considered along with the clinical findings of the horse. The soft tissue structures routinely imaged include the soft tissue structures on the palmar/plantar aspect of the cannon bones as well as the suspensory apparatus and distal check ligament. If excessive digital flexor tendon sheath effusion is observed, examine the soft tissue structures of palmar/plantar fetlock and pastern. Additional ultrasonographic imaging may be performed if there is effusion of the synovial structures or cervical facet disease concerns.

4. Reports
The reporting of exam findings is a crucial part of a successful pre-purchase exam. The use of a template for consistency is key. The verbiage in the report is also important for legality. Words such as “on this day,” “at the time of this exam,” and “not a guarantee” will help remind the buyer that the pre-purchase exam is a variable exam that can change quickly. Include a statement in the report indicating the findings of this exam were discussed with said buyer and trainer or representative and that they have received a copy of the report. Other helpful statements in the report should include the buyer’s responsibility for confirming the show record of the horse. This can entail a significant amount of research and should fall on the potential buyer to put the necessary time into searching for gaps in the horse’s performance record. Communication is vital to the pre-purchase exam, and the more a report exemplifies all the details noted during the exam, the more successful the outcome. Another common form of reporting is videoing the exam. The author will routinely video the horse trotting on a firm surface, on the lunge line, and under tack before and after canter. It is helpful to be able to refer back to the video if the need arises. The veterinary practitioner plays a key role in the purchase of a horse. Taking the time to perform an in depth clinical exam, researching the history of the horse, and recording the findings in a consistent manner, will give the buyer the confidence they need to make the right decision for them.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.
Diagnostic Imaging in the Pre-Purchase Examination

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1. Introduction
Diagnostic imaging is frequently used in the pre-purchase examination. Radiographic examinations are the most common imaging performed and an integral part of the pre-purchase examination. Radiographs are obtained to find performance-limiting or potential performance-limiting orthopedic problems. This requires accurate diagnosis and interpretation of the images presented. When questionable findings arise, further diagnostic imaging investigation may be warranted. Often, several veterinarians, including veterinary radiologists may review the images and offer opinions. At the end of the imaging exam, this information is presented to and discussed with the buyer to consider future athletics and also resale value.

The radiographic examination may consist of specific views of limbs or a complete examination of several anatomic areas depending on the clinical exam and the breed and discipline of the horse. It is important to realize that incomplete studies may result in incomplete results. Radiographic views in each pre-purchase may vary depending on the physical exam, buyer, and buyer’s veterinarian. Common radiographic views obtained in sport horses are listed in Table 1. Patient preparation such cleaning the foot, removing the shoes when possible, and brushing the hair to remove external debris are important starting points in the exam.

The correct positioning and technique of the radiographic views is important to highlight common areas of pathologic change and has been described. Without a complete set of well-positioned radiographs and an adequate technique, radiographic findings may be incomplete and thus misleading (Fig. 1).

Image interpretation is a complicated process. The first part of interpretation is finding radiographic abnormalities and deciphering whether they are within a normal range (normal variants) or a true pathologic change. An in-depth knowledge of anatomy and expected bone change for the age, breed, and discipline of the horse is critical to find the true pathologic change. The second step, and arguably the more important step, is providing a meaningful impression of the radiographs. This requires experience, knowledge of pertinent literature, and often a dialogue with the examining veterinarian.

When forming radiographic impressions, clinical significance of bony and soft tissue lesions can be formed by number of cases seen, case reports, or studies of pre-purchase radiographic exam findings in sport horses and western performance. There is a greater literature base for repository racehorses.
for prevalence and racing performance; however, this can be difficult to apply in sport horses with longer careers well into their teenage years. The unknown, which can be an abnormality that has not been seen before by the pre-purchase veterinarian, may pose a risk. One must rely on radiographic findings (size, shape, location, number, and opacity), age of horse, show record, and lameness exam to form an opinion on whether this will pose a risk for the horse athletically. Additional opinions from specialists in diagnostic imaging and surgery/sports medicine can be and are often obtained to help shed light on abnormalities and clinical relevance for the intended use of the horse. It is important to remember that the radiographic images are a single snapshot in time and do not convey evolving versus static pathologic change. When possible, comparing previous studies is helpful to convey clinical relevance. Nevertheless, the imaging findings are best weighed alongside the clinical exam.

The equine foot is one of the most x-rayed regions for the pre-purchase examination and, thus, one of the most scrutinized. Numerous studies describe pathologic changes in the foot and association with lameness. As with many sites, radiographic abnormalities in the foot may not correlate with lameness. The navicular bone in particular is often scrutinized. The shape, corticotrabeular bone definition, presence of enthesophytes, size and number of distal border synovial invaginations, and distal border fragmentation are often described. The clinical relevance of each of these findings is variable. Sound horses can have a trapezoidal or slightly elongated flexor cortex similar in shape to a chef’s hat on the lateral image. Navicular bone distal margin fragmentation can be seen as an incidental finding. Synovial invaginations are often debated as degenerative changes in the navicular bone. Warmbloods have some normal variation of larger and more numerous synovial invaginations at the distal border compared with other breeds. When considered as a single entity, synovial invaginations may have a minimal association with lameness. However, in the author’s opinion, enlarged synovial invaginations thinning the cortex have the propensity to erode through and become a flexor cortex defect and should be considered a risk. Radiographic findings considered clinically relevant are defect(s) in the flexor cortex, loss of corticotrabeular bone definition, medullary sclerosis, and, to a lesser extent, proximomedial and lateral enthesophytes. Often when interpreting findings, it is several areas of pathologic change in the foot/navicular region that add up and are assessed as a potential risk.

Ossified ungual cartilages were often thought of as a benign process with little clinical consequence,

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**Table 1. Common Radiographic Views in a Pre-Purchase Exam**

<table>
<thead>
<tr>
<th>Joint</th>
<th>Discipline</th>
<th>Views</th>
</tr>
</thead>
<tbody>
<tr>
<td>Front feet</td>
<td>Most</td>
<td>LM, DP, Pa55Pr-PaDi-O (Navicular Skyline), D60Pr-P-O/upright pedal, D60Pr45LM-Pa-O</td>
</tr>
<tr>
<td>Front fetlocks</td>
<td>Most</td>
<td>LM, D15Pr-P-O, D15Pr45LMP-O, D15Pr45MPL-O (include PIP)</td>
</tr>
<tr>
<td>Hind fetlocks</td>
<td>Most</td>
<td>LM, DP (+/− D15Pr45LMP-O, D15Pr45MPL-O)</td>
</tr>
<tr>
<td>Hocks</td>
<td>Most</td>
<td>LM, D45LMP-O, D45MPL-O</td>
</tr>
<tr>
<td>Carpus</td>
<td>Racing, timed events, eventing (+/−)</td>
<td>LM, flexed lateral, DP, D45LMP-O, D60MPL-O</td>
</tr>
<tr>
<td>Stifles</td>
<td>Western performance, dressage, jumping, eventing</td>
<td>LM, C45L-CrM, DP</td>
</tr>
<tr>
<td>Back +/-</td>
<td>(+/−) clinical exam</td>
<td>Lateral</td>
</tr>
<tr>
<td>Neck +/-</td>
<td>(+/−) clinical exam</td>
<td>Lateral</td>
</tr>
</tbody>
</table>

LM, Lateromedial; DP, Dorsopalmar (plantar); Pa55Pr-PaDi-O (Navicular Skyline), Palmaro 55 proximal-palmarodistal oblique; D60Pr-P-O/upright pedal, Dorso 60 proximal-palmar oblique; D60Pr45LM-Pa-O, Dorso 60 proximal 45 medial/lateral-palmar oblique; D15Pr-P-O, Dorso 15 proximal-palmar/plantar oblique; D15Pr45LPM-O, Dorso 15 proximal 45 lateral-palmaro(plantar)medial oblique; D15Pr45MPL-O, Dorso 15 proximal 45 medial-palmaro(plantar)lateral oblique; D45L-PMO, Dorso 45 lateral-plantoromedial oblique; D30M-PLO, Dorso 30 medial-plantarolateral oblique; D45LPMO, Dorso 45 lateral-palmaromedial oblique; D60MPL-O, Dorso 60 medial-palmarolateral oblique; C45L-CrM, Caudo 45 lateral-cranio medial oblique.

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**Fig. 1.** Right hind limb dorsomedial-plantar lateral images. The left image was obtained with the x-ray generator at a 10° angle. Note that the sesamoid bones are not projected proximal to the joint and summate with the plantar process of the proximal phalanx. The right radiograph was obtained with a 25° downward angle and shows a smooth plantar osteochondral fragment (yellow arrow) that was hidden in the left radiograph, illustrating the necessity of well positioned radiographs for a pre-purchase exam.
unless they are fractured. There has been more recent work to inspect this area further on purchase exams.\textsuperscript{15,18,19} The ungual cartilages can ossify in two patterns. The more common pattern is from the base extending proximal and the second is with a separate ossification center more proximal. The junction between the separate center and the base can be irregular and sclerotic. When reviewing this area, it is important to evaluate the ossified ungual cartilage and palmar process for sclerosis (Fig. 2). This can precede a fracture of the distal phalanx.\textsuperscript{18} Ossified ungual cartilages have also been associated with collateral ligament injury.\textsuperscript{15} Ossified ungual cartilages will not likely preclude the horse from doing its intended purpose but should be scrutinized as a potential (low) risk.

The distal phalanx is uncommonly subject to osseous cyst-like lesions but typically are regarded as clinically relevant and a source of lameness.\textsuperscript{19} These lesions are typically unilateral and in the forelimb. Mild signs of osteoarthritis are often encountered in the distal interphalangeal joint, especially in horses that have a long campaign record. In these cases, it is the author’s opinion that symmetry and history are important considerations to convey impressions of risk. Advanced demineralization and irregularity along the solar margins (anatomic diagnosis of pedal osteitis without an underlying cause) in Thoroughbreds may be a consideration, as these may be lame, whereas Warmbloods tend to be less affected by lameness with similar radiographic findings.\textsuperscript{3}

There are often small osteophytes at the dorsoproximal aspect of the (fore) middle phalanx that are incidental. Osseous cyst-like lesions are commonly seen associated with the hind proximal interphalangeal joint (distal aspect of the proximal phalanx)\textsuperscript{21} and are important to include in the radiographic views of the hind fetlock joint. When these cysts are located along the weightbearing surface, the author considers these a risk.

Lesions of the fetlock joint are a common occurrence.\textsuperscript{22} In the sport horse, fetlock osteoarthritis is one of the most common findings. The horses are often competing well at a variety of disciplines and levels with mild to moderate osteoarthritis. Fragmentation of the palmar/plantar tuberosities of the proximal phalanx are often of debate. In racing Standardbreds, there is no difference in race speed or career earnings in horses with fragments or not.\textsuperscript{23} In Thoroughbred sales radiographs, plantar osteochondral fragments can be considered incidental.\textsuperscript{24} Osseous cyst-like lesions (proximal aspect of the proximal phalanx, distal 3rd metacarpal/tarsal bone, or proximal sesamoid bones) are typically regarded as a risk for lameness and resale in sport horses. However, in racehorses, these may not pose a risk for race starts.\textsuperscript{25} Fissures in the sagittal groove of the fore proximal phalanx, seen most frequently in Warmbloods, pose a risk for future lameness (Fig. 3). Once lame, they can be difficult to manage.\textsuperscript{26} The trabecular bone surrounding the sagittal groove is often sclerotic in cases of fissures in the region. These lesions seem to be more commonly encountered in the forelimbs as a clinical entity. Asymmetric enlargement of the vascular

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Fig. 2. Dorsopalmar radiograph of the foot, lateral is to the left. There is moderate sclerosis of the medial ossified ungual (yellow arrow) that extends into the palmar process of the distal phalanx. The lateral ossified cartilage and palmar process are considered normal. This finding can precede fractures in the distal phalanx. These horses may have a low grade, intermittent lameness on presentation.

Fig. 3. Dorso-proximal-palmarodistal projection of the right fore fetlock joint. Lateral is to the left. There is an ill-defined lucent zone in the sagittal groove subchondral bone of the proximal phalanx (yellow arrow). Curvilinear osteosclerosis is distal to the groove in the trabecular bone (red arrow). These lesions pose a risk for soundness and may cycle between lame and not lame once they become active.
channels of the proximal sesamoid bones in racing pre-sales radiographs has been associated with decreased earnings and starts.\(^2^7\) Furthermore, proximal sesamoid bones that are affected have a greater risk of developing suspensory branch injuries.\(^2^8\) Evidence of this radiographic change may spur the veterinarian to examine the branches of the suspensory ligament more closely or perform an ultrasound exam.

Osteoarthritis is a common finding in the distal two joints of the equine tarsus on survey radiographs. This radiograph finding does not tend to correlate well with the presence, duration, or severity of lameness.\(^2^9,^3^0\) However, recent literature suggests this may be performance limiting in 4-year-old Quarter Horses competing in cutting events.\(^4\)

Given the ubiquitous nature of the osteoarthritis in the distal tarsal joints, these findings are often regarded as a treatable entity and not a finding that restricts the horse from doing its intended purpose. Osteoarthritis in the tarsocrural joint, proximal intertarsal joint, and talocalcaneal joint is generally considered a clinically relevant finding and source of lameness. A common area of osteochondral disease is the tarsocrural joint.\(^6,^3^1,^3^2\)

The clinical significance can be variable. In a review of 1,231 sound Dutch Warmblood horses, 13% had evidence of osteochondral disease in the tarsocrural joint. Additionally, Thoroughbred racehorses with evidence of osteochondral lesions in the tarsocrural did not have a reduced number of starts and money earnings.\(^7\)

Signs of effusion in the joint along with the osteochondral fragmentation likely indicate some degree of free fragments or chondral shedding and are a consideration for performance or lameness in a pre-purchase examination.

Stifle lesions are a relatively common finding in sport horses and western performance horses.\(^3^2\) The prevalence of stifle lesions in western performance horses can be as much as 44.5%, with the medial femoral condyle dominating the site of the lesions.\(^3^2\) However, these lesions were not significantly associated with subsequent performance in young Quarter Horses.\(^4\) It is important to note that this study did not follow the horses long term. It is the author’s opinion that cyst-like lesions and articular defects in the femoral condyles pose a risk for the potential buyer and future performance and resale. Osteochondral lesions of the trochlea in young horses can be a source of lameness and effusion. Often, as they start into some work, they present with effusion or mild lameness. In young unproven horses, these lesions are a risk. These lesions can be removed with reasonable athletic outcome but may perform at a lower level or earn less money.\(^3^3,^3^4\) The intertroclear groove may also have osteochondral lesions. In the author’s opinion, small concave defects at the distal aspect of the intertroclear groove are often incidental (Fig. 4). There are known areas that can be challenging to diagnose osteochondral lesions in the stifle. Most notable is the proximal aspect of trochlea.\(^3^5\) These “blind spots” are important to realize and make a concerted effort to evaluate for pathologic change. It is also important to realize normal variations of the equine stifle to avoid overinterpretation. The medial femoral condyle can be flat (with no subchondral bone change) on the caudocranial image. Additionally, the distal aspect of the lateral trochlea has a smooth undulant margin.

Neck and back radiographs are becoming more prevalent in pre-purchase radiographs, especially sport horses. There is minimal literature about cervical articular process osteoarthritis and athletic performance. As horses age, the C5–6 articular process can enlarge without clinical manifestation.\(^3^6\) Additionally, horses can have a variety of pathologic changes in the articular facet joints and disc without historical evidence of neck pain.\(^2\) Slight obliquity may cause an overinterpretation of an articular facet enlargement and signs of osteoarthritis (Fig. 5). Osteochondral fragmentation is an infrequent abnormal finding in the equine neck but is often associated with osteoarthritis. This should be considered as a potential area of performance alteration. As with other lesions, this should be considered with the physical exam. Horses that compete with the head collected, such as dressage, often have mild to moderate osseous proliferation at the origin of the nuchal ligament (funicular) on the occipital protuberance. This is considered incidental most of the time. As the literature continues to
expand, more concrete conclusions can be drawn about potential risks (performance and resale) for the buyer.

Narrowing of the interspinous space (spinous impingement) is known to cause back pain. The spinous processes of the thoracic and cranial lumbar spine are typically easily imaged in the field with most portable machines. The space between the spinous processes is typically widest cranially and progressively narrow through the thoracic spine. The normal space is typically $>4$ mm. The interspinous space can be artifactually narrow by x-ray beam angle and cause overinterpretation. Additionally, there can be mild narrowing and sclerosis at the summit of the spinous processes in asymptomatic horses. Horses that have a higher grade and more vertebral segment effects have an association with back pain. Radiographic examination of the articular processes can be more challenging in the field. These areas are also a known source of back pain. It may be prudent to image these areas with a high-milliamp generator as part of a pre-purchase exam in a horse with back pain. This will help to understand potential areas that may need to be addressed with medical management.

Advanced imaging incorporated into the pre-purchase exam is becoming common practice. This is often used if there are suspicious findings on radiographs or the clinical exam or for a baseline in skeletal health. Ultrasound is easy to perform in the field and quickly answers clinical questions of abnormalities in the soft tissue and bone-ligament interface. Standing magnetic resonance imaging of the foot is the most common region of anatomy reviewed by the author in pre-purchase situations and can be helpful to ease or confirm the buyer(s) concerns when radiographic changes are outside of what is expected for the horse based on breed, age, and discipline. Scintigraphic evaluation is often used to get a baseline of the horse and answer specific clinical questions (especially in horses that are back sore, have pelvic region pain or abnormal flexions in the face of normal radiographs and ultrasound).

Imaging in the pre-purchase examination helps in the evaluation of potential risk, either from future performance or resale. It is important to interpret findings with the lameness/physical exam and known show record if available. A discussion of risk for imaging findings may involve the examining veterinarian along with veterinary specialists or experienced veterinarians in equine diagnostic imaging.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

1. Park RD. Optimal radiographic views for evaluating Thoroughbred yearlings—quality control of the radiographic im-


Equine Pre-Purchase Examinations in the Sport Horse between Europe and the United States

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1. Introduction

Horses are used in sports worldwide, in many different disciplines, and on varying levels, ranging from pleasure to international competitions, with three disciplines included in the Olympic Games. Equine sports hold a special place in the sports world, as it is unique that the performance and success of a human athlete is highly dependent on their quadruped companion's qualities. Consequently, horses are bought and sold all over the world. To evaluate horses for sale, performance and character play important roles, but once a desirable sports partner is found, the limiting factor may be the animal's health. This is when veterinarians are consulted to advise potential buyers on their decision and the associated risks.

In our veterinary profession, there are few issues debated with as much controversy and none result in as many legal disputes as this responsibility—the pre-purchase examination (PPE).1

In this discussion, the various aspects and the international differences in PPEs of the sports horse will be presented.

2. First Contact—Making the Contract

Between the first contact and the actual PPE, a lot of information has to be gathered. Many purchases are very complex because of value of the horse, people involved (seller, buyer, trainer, vendor, additional veterinarians), and the high risk for potential litigation. While it is generally excepted that a PPE should be documented meticulously, it is highly recommended to also obtain a written agreement about the extent of the PPE in detail.2,3 The following information should be obtained:

- Clear identification of buyer, seller, and possibly vendor
- Clear identification of the actual customer who is paying the bill, entitled to get the results of the exam, and decides who else is allowed access to this information
- Purchase price
- Detailed information on the extent of the exam requested

Typically a basic fee is charged for the complete physical examination, then costs added for all additional examinations (i.e., endoscopy, radiography, ultrasonography, objective-motion analysis, detailed reproductive examination, etc.). An amount of 0.6% of the horse’s purchase price (as stated by the client)
is then added to cover the practice’s liability. The examination itself is no different between horses being sold for $5000 vs $3,000,000.

It is essential for the examining veterinarian to know the horse’s purchase price to decide whether they can perform the examination. If the purchase price is higher than liability coverage, the contract with the buyer is restricted to that amount or the PPE should be declined. Veterinarians should also decline performing the PPE if they do not feel experienced enough to evaluate the horse, if the horse is intended for a use that they are not familiar with, or if examinations are requested with which they are not familiar.

If the horse has been examined or treated by the examining veterinarian at an earlier time, this should be disclosed as well. This aspect is tricky, and this should first be discussed with the owner and persons who presented the horse previously. In some cases, it is better to decline the PPE because of conflict of interest. If applicable, try to contact the buyer’s regular veterinarian to make sure the exam covers all his/her requests.

All information should be completed by the seller AND buyer (including credit card details) and requested before starting the examination.

3. The Examination

Before starting a complete physical examination at rest, the horse is identified using an equine passport and microchip scanner, the vaccination status is verified, and a questionnaire on the horse’s history including previous health issues, feeding, stabling, deworming, shoeing, dental care, prior surgeries, etc. is completed and signed by an authorized agent. If the horse was examined and/or treated by the author’s practice at an earlier stage, this is disclosed. For confidentiality reasons, care should be taken to discuss this with the previous client first. History of former diseases and possible surgeries are also required to be disclosed by the seller.

A thorough examination of the horse at rest is performed first. This physical examination includes respiratory and digestive tract, cardiovascular system, eyes, skin, and inspection and palpation of the musculoskeletal apparatus. It is frequently debated whether conformational abnormalities should be discussed. Comments on conformation should only be made when a clear medical issue exists with risk for future performance. A very short or long back, broken toe axis, underrun heels, asymmetric pelvis or front feet are a few examples which should be commented on. Shoeing, especially with so-called orthopedic or “unconventional” shoes are documented in the report. Form, shape, and quality of the feet, as well as examination with hoof testers give us important information. The motion-palpation of neck, back, and limbs completes our static examination.

Special attention is given to the examination of the horse in motion when dealing with an equine athlete. The horse is first observed at the walk and trot on a hard surface: straight line, small figure eight, small circles, and backing up are all included. On soft ground, the horse is observed on a lunge line at the walk, trot, and canter. It is preferable to see the horse with its head loose, not tied down, so the horse is free to balance itself as it likes. Apart from symmetrical gait, special attention is given to position and movement of head and neck, as well as to the transitions between different gaits. Respiratory and circulatory systems are also examined during and after exercise on the lunge line.

An objective gait analysis system called Qualisys Motion Capture for most PPEs. This optical-based system is connected to 20 high-speed infrared cameras with a sampling frequency set to 100 Hz. Spherical reflective markers are attached in clusters on the head, withers, and pelvis by the use of double-sided adhesive tape. The marker setting may be expanded to limbs and back to monitor range of motion. Synchronized video recordings of each measurement are made. This technique allows measuring even the slightest asymmetries, get an overview of the complete motion pattern of a horse, and communicate the results (including associated graphs and videos) with customers and veterinarians worldwide. It is not uncommon for sellers to initially question this type of examination, being anxious that one would “see too much” or that small asymmetries would be detected with the objective analysis system undetectable to the human eye. However, most of these people come back with other horses, to have this examination performed because they are convinced of its additional value.

The examination of the locomotory system is concluded by observing the horse under tack in all gaits, straight lines, and circles. Specific exercises may be performed if requested by the buyer, such as half passes and collections for a dressage horse or jumping over fences for eventers or show jumpers.

Examination under tack is not a standard in Europe. In fact, it is quite controversial. Many colleagues think the evaluation of the horse under tack is the sole responsibility of the rider/trainer. However certain lamenesses or behavioral problems may be missed if the under saddle examination is not performed.

Comments on the character of the horse may be included, especially if we consider it a risk for the buyer. An inexperienced rider purchasing a stallion that is difficult to handle may pose a risk for the buyer and this should be given attention. The same animal may not be a problem in professional hands. An older horse that kicks when trying to do a flexion test may be worth mentioning, while in a young horse having travelled from the stable for the first time, this should be put in perspective.
Radiographs hold a very important role in the decision process of purchasing a horse. Since the imaging part of the PPE will be covered separately, a few comments are added here. The so-called “standard” set of radiographs varies enormously. The requested number of radiographs in the United States varies between 24 and 64. In Europe, the requested standard views vary as well. The standard is 18 views in Germany as of 2018, while previously it has been 12. In the Netherlands, typically 18 radiographs are obtained; in Belgium, 22; France has no common “standard”; Sweden, 12; Italy, 23 or 32; United Kingdom, 28; and so on. In most countries these recommended standards are not based on scientific evidence but on experience and judgment of opinion leaders in equine medicine in the particular countries. A first step toward developing a more standardized PPE could be a consensus on which views are most important, resulting in a standard number of radiographs. Regarding the review of radiographs, a trend toward evaluation of the images by board-certified radiologists is notable. It is important to have specialists to consult to seek their advice; however, the final evaluation and judgment of potential clinical relevance of radiological abnormalities should be performed by the practitioner or clinician responsible for the PPE. If radiographs are being sent around the world, establishing who is liable for their interpretation should be discussed with the client. It cannot be emphasized enough that it is important to read the horse, not just the radiographs. Too many sales are being “killed” by accurate radiograph interpretation descriptions without clinical background information.

Ultrasonographic examinations are increasingly requested during PPEs in most places. It is important to remember that ultrasonography is a dynamic examination and the evaluation of images without short video clips may be very misleading. Even short video clips may not give the most accurate information. A written report on the ultrasound findings is favorable.

Additional examinations such as MRI or scintigraphy are not routinely performed, although may be advised in cases of unclear clinical or radiographic findings.

Blood samples are always drawn for examination on substances (doping). The client has the choice between immediate examination or storage of the sample for a defined amount of time in the clinic. Complete blood cell count and biochemistry analyses are performed routinely.

4. Documentation
As in all aspects of veterinary medicine, documentation is the key to success if it comes to litigation. Documentation should include all telephone calls, discussions, and explanations besides the examinations and imaging. The witnesses should also be documented: all people present during the communication and examination, including interns and externs, technicians, and anybody else in attendance.

5. Report
The report should contain a summary of the examination, and not simply a copy of notes taken during the examination. In some countries recommendations and even templates are provided by veterinary associations. Radiographs sent across the globe should always include an opinion and written report of the veterinarian who produced the radiographs. The decision to purchase or not purchase a horse is solely the buyer’s decision, not the veterinarian’s. Not even the recommendation is the veterinarian’s job! The report should list the findings of the examination, followed by the prognosis of those findings. An opinion that “nothing speaks against the use in sports of this horse, based on today’s medical examination”, may be stated, but it is unwise for a veterinarian to tell the buyer to proceed with the purchase or not, and absolutely impossible to predict the sports career of the four legged companion.

It is beyond discussion that the choice of words in the report is key to the satisfaction of the clients, both buyer and seller, and for the veterinarian’s own protection. How can one differentiate between a slight asymmetry and a lameness? Is it possible to state a horse as “slightly off,” but fit to do his job? Does one mention very slight stiffness in the back or a marginal exostosis in the tibia plateau of a stifle? Of course the risk for possible litigation is reduced by having the majority of horses fail the PPE. However, over time it will hurt one’s reputation when too many of these “failed” horses perform very well. Experience is the key to successful judgment.

One also has to keep in mind that a horse changing stables or even continents will have to deal with different food, different equipment (saddle and other tack), new training techniques, riding style, show schedules, different footing, farrier, etc., so there is an associated risk that the horse will not function the same way as it did under its former circumstances. These changes have to not only be discussed with the buyer, but also advice has to be given to prevent future problems related to possible management changes.

6. Conclusion
The amount of legal cases involving veterinarians as well as the controversy regarding many aspects of the PPE show that increased mutual understanding needs to be sought regarding this essential and important part of the job. Communication, discussion, and an open mind will be necessary to start down a road toward more uniformity in the performance of PPEs. Young and unexperienced veterinarians should seek advice from experienced colleagues. However, even for experienced clinicians a second opinion should be consulted as often as possible. However, different experiences with certain changes, as well as different opinions, will al-
ways remain. It is then essential to listen respectfully to the opinion of others, and state one’s own opinion in a way that it is just that, an opinion, not an indisputable truth.

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Declaration of Ethics
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References
How to Maximize Standing Chemical Restraint in a Field Setting

John A.E. Hubbell, DVM, MS, DACVAA

1. Introduction
Equine veterinarians utilize sedative drugs alone and in combination to facilitate the performance of a wide variety of procedures with the horse in a standing position. Most standing procedures, such as radiography, laceration repair, biopsy of a mass, or routine dental examination and float are of short duration with local anesthesia included, as needed. Typically, veterinarians adopt a primary drug or drug combination as their routine method of producing a compliant animal. The choice of drug or drug combination is based on a number of factors including drug availability and cost, desired rapidity of onset and duration of action, available assistance and facilities, and perceived predictability and reliability of the technique. In addition, regulatory restrictions regarding drug use vary between jurisdictions, thus limiting choice. For example, a recent survey indicated that medetomidine and romifidine are more frequently administered in Europe than in North America and opioids tend to be used more widely in hospitals settings compared to field settings. Similarly, according to a 2010 survey of the membership of the American Association of Equine Practitioners, 70% of equine veterinarians use drug cocktails (combinations) as their first choice for standing chemical restraint. Detomidine, alone or in combination, was the first choice of the majority of respondents followed by xylazine, alone or in combination.

Presumably, most horses respond appropriately to the veterinarian’s adopted drug protocol, but, on occasion, the intended result does not occur. In such situations, the veterinarian might repeat a portion of the initial administration of the same drugs, add additional drugs to the protocol, increase physical restraint (e.g., application of a twitch or the elevation of a limb), or perhaps postpone the procedure to a later date. In addition, veterinarians are increasingly choosing to or being asked to perform more extensive and potentially more painful procedures with the horse standing. Examples of such procedures include tooth repulsion, enucleation of the eye, cryptorchid castration, laryngoplasty, ovarioectomy, or even lag screw fixation of a metacarpal/tarsal condylar fracture. The choice of a standing procedure rather than general anesthesia is based on a number of factors including cost, the availability of reliable assistants and specialized equipment, the accessibility or inaccessibility of a referral hospital, practitioner comfort level with the desired procedure, and the recognized risks associated with general anesthesia of the horse. The requirements for sedation, analgesia, and restraint to ac-
complish these more complex and potentially more invasive surgical procedures frequently exceed those needed for the shorter, simpler procedures more commonly performed. The purpose of this presentation is to describe how to amplify the sedative and analgesic effects of basic sedation protocols and how to produce maximal standing chemical restraint for more extensive procedures in the field setting.

2. Review of Commonly Used Drugs

Phenothiazine Tranquilizers

Phenothiazine tranquilizers are used to produce calming and relaxation. Phenothiazines block the action of neurotransmitters centrally and peripherally and cause alpha adrenergic blockade leading to arterial hypotension. The onset of action after parenteral administration occurs within 15 to 30 minutes but peak effects may not be seen for up to 45 minutes. The duration of sedation depends on the dose administered but frequently lasts for 6 to 10 hours (Table 1). Minimal muscle relaxation or ataxia occur. Acepromazine does not produce analgesia but may make analgesic drugs more effective. Increasing the dose of acepromazine does not usually produce a greater effect but the duration of action is increased. In stallions and geldings, phenothiazine administration rarely causes persistent penile paralysis. Acepromazine is infrequently used as the primary drug for standing chemical restraint because of the depth of sedation produced, the comparatively long time to peak effect, and the lack of analgesia. Acepromazine is used in some combinations because it provides a consistent level of background tranquility that facilitates a more consistent level of overall restraint.

Benzodiazepines

Benzodiazepines are primarily used to augment muscle relaxation and as anti-epileptic agents in the horse. Benzodiazepines do not produce significant sedation or analgesia. Both midazolam and diazepam can produce significant muscle relaxation, weakness, and apparent ataxia when given in high doses so caution should be exercised when they are used as part of a protocol for standing chemical restraint. Benzodiazepines are primarily used as adjuncts in dental procedures because they are reported to reduce chewing and tongue movement.

α₂ Agonists

α₂ agonists produce sedation with muscle relaxation, ataxia, and analgesia when given orally, intravenously (IV), or intramuscularly (IM) to horses. The pharmacologic/pharmacodynamic effects of the α₂ agonists are similar to one another with increases in arterial blood pressure and decreases in heart rate, cardiac output, and respiratory rate frequently seen. All produce analgesia, the duration of which is consistently shorter than the accompanying sedation. Xylazine, detomidine, and romifidine are approved for use in the horse in the United States. Elsewhere, medetomidine and dexmedetomidine are used. In large part, the effects of the agents are qualitatively similar with differences centering on dose (due to receptor specificity and potency), time to onset, duration of action, and degree of analgesia produced. The level of sedation produced by administration of an α₂ agonist is more pronounced than that produced by phenothiazine administration. Horses that have received α₂ agonists assume a “head-down” or “saw horse” stance and frequently shift their weight from side to side. Occasionally, these effects are problematic, particularly when the horse has ataxia and the procedures include sampling of cerebrospinal fluid and/or cervical radiography. In such instances, small doses of shorter-acting α₂ agonists, such as xylazine, may be the best option. Romifidine, in locations where it is available, is another potential choice for horses with ataxia. IV administration produces a quicker onset of action, an increased intensity of effect, but a shorter duration of effect. Infusions of α₂ agonists for standing surgery are gaining popularity. The use of constant rate infusion reduces the ups and downs of repeat bolus administration and frequently lowers the total dose of drug administered.

Opioids

Opioids are used to produce analgesia and augment the effects of sedatives and tranquilizers. When administered alone to pain-free animals, opioids can cause nervousness and excitability, so prior sedation is required. Butorphanol is a synthetic opioid agonist/antagonist that is approved for use in the horse for the treatment of abdominal pain. Butorphanol is included in a number of combinations used for minor standing procedures because the dose of other drugs (such as α₂ agonists) can be reduced but it may not produce the level of analgesia and restraint required for more extensive procedures even when local anesthesia is included. The duration of action of butorphanol is longer than that seen after butorphanol and the potential for restlessness or excitement is similar. A number of other opioids including morphine and meperidine have been used to produce standing chemical restraint. Horses may remain sensitive to touch so local anesthesia should be incorporated with the technique. In the author’s experience, the level of augmented sedation and analgesia is greater with morphine and meperidine than it is with butorphanol or butorphanol. Naloxone can be used to antagonize morphine or meperidine, if necessary. Renarcotization (excitement) occasionally occurs and is best treated by repeat administration of naloxone or tranquilizer administration.

Ketamine

Ketamine infusions are beginning to be incorporated into standing restraint protocols in an attempt to increase analgesia. The dose administered ranges...
from 0.4 to 1.2 mg/kg/hr given at a constant rate. The effectiveness of the technique seems to depend on the type of pain being induced or treated with excellent results seen for patients with burns and some utility in dental procedures.

**Lidocaine**

Lidocaine infusions provide anti-nociception to electric stimuli without producing significant sedation in conscious horses, but its effects on visceral pain are unproven. Infusions are usually well tolerated, but bolus administration may be associated with hypotension and ataxia.

### 3. Approach to Maximal Standing Chemical Restraint

Maximal standing chemical restraint is approached de novo in some patients but is frequently performed as an “add on” when the initial sedative drug or drug combination is ineffective. Initially, an assessment should be made with regard to why the initial administration was ineffective. Were the correct drugs at the usual doses administered? If the drugs were intended for IV use, where they administered IV? Was sufficient time allowed for the drugs to take maximal effect before the procedure was begun? Was the environment conducive to the production of a sedated state? Was the analgesia produced sufficient for the intended procedure? Is there something about this horse that was underestimated or misinterpreted? Frequently, when an attempt at standing chemical restraint has failed, some combination of these potential problems may have occurred. The veterinarian must make a determination whether to continue with the current program or postpone the procedure until a later date. If the decision is to continue, the veterinarian should determine the length of time from the initial administration of sedative to the present. As an example, the duration of action of IV xylazine is approximately 30 minutes. If you are outside of this window, you are essentially starting over. If the initial drug was detomidine or romifidine, your window is approximately 45 to 60 minutes.

If the horse was somewhat sedate after the initial administration of drug but not to a point where the procedure could be performed, the author recommends the following general protocol: Readminister the initial dose of your preferred drug or drug combination and establish venous access with a catheter. The placement of a catheter is important because it reduces the stimulation of multiple needle sticks and assures drug delivery into the vascular space. Dilute detomidine (10 mg) or xylazine (1000 mg) in normal saline (250 or 500 mL) and infuse 25% of the volume at a fast drip rate. If the desired level of sedation is attained, slow the drip rate and perform the procedure. If the level of sedation becomes inadequate, administer an additional 25% of the volume at a fast rate, then slow the rate to titrate the level of sedation. Butorphanol (5–10 mg) could be added to the infusion to provide addi-
tional analgesia if desired or required. The dose of drugs indicated should provide at least 60 minutes of maximal sedation in a previously sedated horse of average size and health status.

If the procedure is postponed to a later date, the author recommends the use of a combination of detomidine and either morphine or meperidine to produce maximal standing chemical restraint. Administer detomidine (0.01 mg/kg IV or 0.02 mg/kg IM) and either morphine (0.1–0.3 mg/kg, IV) or meperidine (0.2–0.6 mg/kg, IV) after the local blocks have been completed and taken effect. This is the point of maximum effect of the administered drugs. If additional restraint is required, increase the rate of administration of the detomidine infusion and provide additional physical restraint (twist or elevation of a leg), if appropriate or possible. This technique has worked well for the author for procedures such as ovarioectomy, internal fixation of condylar fracture, tooth root removal, andenucleations.

General anesthesia should be considered if this maximal standing chemical restraint technique is insufficient to allow performance of the procedure. It is reported that additional analgesia can be produced by adding ketamine to the detomidine infusion. The author has not found the addition of ketamine to be consistently useful in the horse as it is in other species. The use of subanesthetic ketamine infusions in combination with other analgesic drugs, such as tramadol, has been shown to be effective in reducing the signs of pain associated with chronic laminitis.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

How to Get 15 Minutes More Out of Your Field Anesthesia Technique

John A.E. Hubbell, DVM, MS, DACVAA

1. Introduction
Approximately 50% of equine veterinarians anesthetize horses for short-duration procedures every week. The most frequently used technique is the administration of intravenous (IV) ketamine or ketamine in combination with a benzodiazepine (diazepam or midazolam) after sedation with xylazine. The combination of xylazine and ketamine became popular after the publication of a 1977 paper describing the use of a new technique for short-term anesthesia in the horse. Xylazine-ketamine anesthesia has been administered to many horses during the past 40 years with relatively good results. Modifications of the xylazine-ketamine technique have been made as practitioners have encountered problems and have sought to improve the quality of the anesthetic protocol. The major problems associated with xylazine-ketamine anesthesia are related to 1) inadequate xylazine sedation prior to ketamine administration producing induction failure, 2) inadequate muscle relaxation during recumbency, and 3) too short a duration of anesthesia. Many of the shortcomings of xylazine-ketamine anesthesia have been overcome by adding muscle relaxant drugs to the anesthetic protocol, typically either guaifenesin or a benzodiazepine such as diazepam or midazolam. The addition of the muscle relaxant shortens the time to recumbency, improves the quality of the anesthesia and increases the duration of anesthesia from 14 minutes when xylazine and ketamine alone are used to approximately 20 to 25 minutes. Typically, 15 to 20 minutes of anesthesia is sufficient time for experienced practitioners to perform a variety of simple surgeries such as castration, removal of a small skin mass or debridement and closure of a wound. Occasionally, unforeseen circumstances or complications necessitate lengthening of the anesthetic period. The purpose of this paper is to propose methods for extending the duration of short-term IV anesthesia by 15 minutes.

2. Extending Xylazine-Ketamine Anesthesia Beyond 15 to 20 Minutes
Repeating Xylazine-Ketamine
If anesthesia needs to be extended because of unforeseeable circumstances, such as encountering a hernia while castrating a stallion, an additional dose of xylazine-ketamine can be administered. The drugs are given at the rate of 30% to 50% of the initial dose (xylazine 0.5 mg/kg and ketamine 1.1 mg/kg), combined in the same syringe. The administration of a second dose of the combination extends the anesthetic period approximately 10 minutes. The administration of additional doses...
beyond the single redosing is discouraged because the quality of the anesthetic state and the recovery from anesthesia worsen in the experience of the author. The constant infusion of a combination of xylazine and ketamine is reported.\(^7\) Infusion of xylazine (35 mg/kg/min) and ketamine (120 mg/kg/min) maintained anesthesia for 60 minutes in a group of research horses not subjected to surgery.

**Guaifenesin Recipes**

One of the most popular methods of extending IV anesthesia for up to 60 minutes after xylazine-ketamine anesthesia is to use a guaifenesin recipe (combination). Guaifenesin is approved for use in the horse but is not marketed in the United States. Guaifenesin is available in 1-L bags from compounding pharmacies. Guaifenesin (5%) solution can be combined with xylazine and ketamine to produce a solution that is called “GKX” or “Triple Drip.”\(^8\) “Triple Drip” is formulated by taking 1 L of 5% guaifenesin and adding 1000 to 2000 mg of ketamine and 500 mg of xylazine. The combination is administered at a rate up to a rate of 2 mL/kg of body weight/hour. The combination produces excellent muscle relaxation and suitable analgesia. The combination is not usually used for induction of anesthesia because of uncertainty when recumbency will occur. If an extended period of anesthesia is anticipated, the infusion can be started after induction once the horse has been positioned for surgery. The degree of muscle relaxation and lack of movement are the best indicators of the depth of anesthesia. The quality of recovery is generally good if the anesthetic period is kept to less than 1 hour. “Triple Drip” should not be used for anesthetics greater than 1 hour in duration unless oxygen supplementation and respiratory support is provided.

**Midazolam Replacement for Guaifenesin**

Midazolam, a water-soluble benzodiazepine, can be used to replace guaifenesin in “Triple Drip” and other \(\alpha_2\) agonist–ketamine combinations for extending short-term field anesthesia.\(^9\)\(^-\)\(^11\) The usual quantities of xylazine (500 mg) and ketamine (1000–2000 mg) are added to 1 L of isotonic fluids. Midazolam (25 mg or 5 mL/L) is added instead of guaifenesin. The resultant solution is dosed at the same rate as conventional “Triple Drip” (2 mL/kg/hr, IV). Smaller volumes (250–500 mL) can be formulated if the anticipated duration of anesthesia is shorter than 60 minutes, reducing cost and wastage. The effects are similar to conventional “Triple Drip” and the cost may be less expensive depending on your source of guaifenesin.

3. **What if I Know I Need Additional Time Before I Induce Anesthesia?**

There are two anesthetic regimens that produce 30 to 40 minutes of anesthesia from a single injection. The combination of xylazine and tiletamine-zolazepam can be used to produce good-quality anesthesia for 30 to 40 minutes.\(^12\) Tiletamine is a drug similar to ketamine and zolazepam is a benzodiazepine, similar to diazepam and midazolam. Xylazine (1.1 mg/kg) is administered IV in order to produce profound sedation and relaxation. Tiletamine-zolazepam (1.1 mg/kg) is given following the onset of full sedation. Induction is smooth and tends to be somewhat quicker than that seen with xylazine and ketamine. The quality of anesthesia is similar to that with xylazine-diazepam-ketamine in that muscle relaxation is excellent. Respiration is depressed but remains adequate for the period of recumbency. Recoveries are not as crisp as seen with the xylazine-ketamine combination because of the greater degree of muscle relaxation. Detomidine and detomidine-butorphanol have also been used prior to tiletamine-zolazepam. The addition of detomidine prolongs the anesthetic duration but the quality of the recovery suffers. The administration of a combination of ketamine (0.5 mg/kg), tiletamine-zolazepam (0.7 mg/kg), and detomidine (0.01 mg/kg) has been investigated for anesthesia for castration.\(^13\) The combination is prepared by reconstituting 500 mg of tiletamine-zolazepam powder with 4 mL of ketamine (100 mg/mL) and 1 mL of detomidine (10 mg/mL). The mixture has been administered after xylazine sedation at a rate of 0.007 mL/kg, IV (app 3 mL/450 kg). The combination produces excellent induction to anesthesia with intraoperative arterial blood pressures higher than those seen with most other techniques. Duration of anesthesia is longer than xylazine and ketamine and recoveries usually require assistance.

4. **Discussion**

Xylazine and ketamine have been successfully used to produce short-term IV anesthesia in horses for over 30 years. The addition of diazepam or midazolam extends the period of anesthesia and augments the quality of the anesthetic period by producing improved muscle relaxation. Longer periods of anesthesia can be produced by administering additional doses of xylazine and ketamine but guaifenesin or midazolam recipes incorporating xylazine and ketamine produce improved results in terms of the quality of the anesthetic period and smoother, but typically, longer recoveries from anesthesia. The improvement in the quality of anesthesia is primarily due to the augmented muscle relaxation and minimal additive sedation produced by the administration of guaifenesin or a benzodiazepine, such as midazolam. As stated, the addition of these drugs typically extends the duration of anesthesia but at a cost of prolonging the recovery period and causing the horses to be somewhat weaker and potentially have a degree of ataxia when they attempt to stand, compared to short-duration xylazine-ketamine anesthesia. Typically, such horses benefit from assistance, such as steadying the head and tail as the horse moves to regain its feet.
Horses are more difficult to anesthetize than the other common domestic species. Total IV anesthesia may be safer than inhalant anesthesia, perhaps because it is usually of shorter duration. Both oxygenation and cardiovascular function are affected deleteriously when horses are placed in lateral recumbency, thus every step should be taken to minimize the duration of anesthesia. Suboptimal oxygenation is apparently well tolerated for up to 60 minutes of anesthesia but oxygen supplementation should be considered for all anesthetized horses. Typically, respiratory rate and depth of respiration and pulse rate and strength are the primary parameters measured during field anesthesia. They should be assessed at 5-minute intervals and recorded at least every 10 minutes. Respiratory rate and pattern are good monitors of anesthetic depth when horses are anesthetized with protocols incorporating ketamine. As the depth of anesthesia increases, respiratory rate slows and horses increasing “breath hold” at peak inspiration (apneustic breathing). If the “breath hold” lasts longer than 2 to 3 seconds, the infusion rate should be slowed. Persons performing IV anesthesia on a regular basis routinely should consider the purchase of an oxygen tank and regulator in order to facilitate emergency oxygenation and ventilation of the patient. Horses can be ventilated by adapting a nasogastric tube onto a pressure reducing valve attached to an oxygen tank. The tube is slid up one nostril and the nasal openings are occluded. The nostrils are released when the chest wall rises to a normal inspiratory level. The process is repeated until spontaneous ventilation resumes. The techniques described produce tolerable levels of cardiovascular depression but as anesthesia is extended the importance of monitoring increases.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

How to Manage “Other Equines” Like Minis and Mules

Nora Matthews, DVM, DACVAA

1. Introduction
Anesthesia of all equine species and variations (hybrids and sizes) is very similar. However, modifications are needed for some patients. First, physical assessment of the particular patient must be performed. Careful assessment of general health and patient temperament, available facilities, and procedure to be performed are critical to successful anesthesia. For an equine patient outside the “norm,” the important questions to ask are, what is different about this patient and how will that affect how I manage it?

2. Specifics for Minis
For instance, if we look at miniature horses, what is different about them? First, they are small; very small. Drug doses must actually be calculated to small volumes. If the average mini horse is 100 kg, that means the average preanesthetic dose for xylazine is about 1 mL (100 mg/mL), much less than the 5–6 mL for a “standard” horse. Especially when using the combination of xylazine-guaifenesin-ketamine (triple drip) for maintenance of injectable anesthesia, drip rate should be carefully quantitated, (rather than running as open flow from a 1-liter bag or bottle) to avoid a drug overdose. For example, since the usual approximate dose for triple drip is 2 mL/kg/hour, a mini would only require about 100 mL/hour; this rate is difficult to control unless carefully observed. Transferring to a smaller container is recommended to prevent overdose. If anesthesia will be maintained with an inhalant, it is usually necessary to use a small-animal circuit to avoid the dead space and resistance of a large animal breathing circuit. This is especially true for miniature horse foals, which may only be 15–20 kg bodyweight.

Also, beware of problems that may occur with dwarf minis; hypoplastic tracheas might require extremely small endotracheal tubes and abnormal head shape and anatomy may make intubation very difficult. In the author’s experience, multiple anatomic abnormalities may occur together in dwarfs.

Another problem common to minis is that many of them are very naughty and may not cooperate for injections. Despite their small size they can put up a good fight. The author will try to quit before getting them really agitated and administer oral detomidine® (at the label dose). It is usually possible to administer an oral drug and after 40 minutes they are usually well-enough sedated to continue with other sedatives and anesthetics, as needed as well as clipping over a vein for better visualization. This is off-label use of detomidine.
gel but the author has used it in many equines (i.e., donkeys, mules, and mini horses) prior to general anesthesia. The author reduces subsequent xylazine or detomidine based on how sedate the patient is and induced with normal doses of ketamine (2.2 mg/kg IV).

3. Specifics for Mules
Mules are a hybrid of horse and donkey. Since the origin of the donkey likely occurred in desert areas, they have physiologic differences from the horse that allow them to survive in a desert environment. This desert adaptation seems to affect the pharmacokinetics of many of the anesthetic drugs we use. The pharmacokinetics of many drugs have not been specifically researched for mules; donkey doses may be helpful. In short, one must usually give more drug or at shorter intervals. For instance, sedation of a mule with xylazine requires giving about 50% more xylazine (i.e., 1.6 mg/kg IV) to produce good sedation. Induction of anesthesia with ketamine will work, but a standard dose of 2.2 mg/kg ketamine will not last the 15–20 minutes typically seen in horses; an 8–10 minute duration is more common. So the practitioner must be prepared to repeat the dose if more time is needed. As with any equid, this will depend on the patient’s temperament and health status. A draft mule will likely require less sedation and anesthesia than a racing-type mule. Also, be aware that any sick mule is likely much sicker than you might observe or anticipate. It may be harder to evaluate the degree of pain or illness unless you know the animal extremely well. The owner is probably best able to judge how sick the patient is. Other differences in handling and management have been well discussed elsewhere.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.

References and Footnote

*Dormosedan gel, Zoetis, Parsippany, NJ 07054.
How to Anesthetically Manage Foals for Minor Surgical Procedures in the Field

Lori A. Bidwell, DVM, DACVAA

1. Introduction
The seasonal nature of anesthesia for foals complicates an already stressful process for most anesthetists. A neonate (less than 1 week of age) and a 4-month-old foal are very different in their response to handling and anesthetics. Understanding some of the basics of anesthetic choices and handling for foals makes surgical procedures in the field less stressful.

2. Materials and Methods
The drugs butorphanol tartrate\textsuperscript{a}, xylazine\textsuperscript{b}, detomidine\textsuperscript{c}, ketamine\textsuperscript{d}, midazolam\textsuperscript{e}, epinephrine\textsuperscript{f}, and “Triple Drip”\textsuperscript{g} are basics that should be on hand for foal anesthesia. Lidocaine\textsuperscript{h} and propofol\textsuperscript{i} are useful adjuncts for the process. Equipment that should be on hand for an anesthetic case in the field includes endotracheal tubes (10 mm ID and 12 mm ID), an ambubag, intravenous catheters, isotonic fluids, primary sets, towels or blankets, and sterile artificial tears or ophthalmic ointment. An anesthetic record should be kept for every procedure involving general anesthesia. The record should include the patient name and owner name, the date of the procedure, location of the procedure, drugs and dosages used, and at minimum, a record of ventilation and heart rate during the procedure. An anesthetic record is an important step in minimizing legal trouble if any complications arise during the procedure.

Sedation of the average neonate (75 kg) is achieved with 2 to 3 mg butorphanol combined with 2.5 mg midazolam IV. Most foals will become recumbent from this sedation and this is adequate to perform minor surgical procedures with local anesthesia (entropian repair, cast or bandage changes, etc.). Induction of neonates can be achieved with 2 mg/kg ketamine combined with 5 mg midazolam with the resulting anesthesia lasting 20 to 30 minutes. An alternative induction drug for neonates and foals less than 200 kg is propofol. A bolus of 2.0 mg/kg IV for induction results in 10 to 15 minutes general anesthesia with a smooth and rapid recovery. An intravenous lidocaine bolus of 0.25 to 0.5 mg/kg can enhance relaxation and result in an additional 5 minutes of recumbency. The mare should be present for sedation and induction of anesthesia. If possible, keep the mare with the foal through the entire procedure. If the mare must be separated from the foal or is anxious, she can be sedated with a combination of acepromazine/xylazine, or detomidine.

Foals 6 months of age or older require drug protocols similar to adults. In fact, at 6 months of age,
most foals respond to drugs as an adult horse with maximum drug requirements. Xylazine (0.8 mg/kg) alone or combined with butorphanol (0.01 mg/kg) for sedation followed by ketamine/midazolam (2.2 mg/kg and 0.08 mg/kg) for induction results in 20 to 30 minutes of general anesthesia for field procedures. Maintenance of anesthesia can be achieved by using additional boluses of ketamine (0.5 mg/kg IV) or using a combination of guaifenesin (50 g), ketamine (1 g), and xylazine (500 mg). Guaifenesin can be replaced with midazolam (50 mg midazolam as a replacement for 50 grams guaifenesin).1 This is typically administered at 1 drop per 4 seconds in neonates or foals using a standard 15 drops/mL extension set. In adults, a bolus of 1/3 of the liter bottle is typically required for general surgical anesthesia. In foals, a bolus can result in hypotension or significant ataxia in recovery and is therefore not recommended.

Recovery of anesthesia rarely requires sedation for neonates and foals. Recumbency can be maintained with light restraint over the neck. Although menace response is useful to determine arousal in older foals, it is a learned response and unknown to neonates and young foals. Tongue tone (ability to pull the tongue back into the mouth) and strap muscle tone in the neck can be useful in older foals as indicators of arousal. When the foal appears alert and responsive to vocal signals, use a hand on the tail as an aid in recovery. The front end can be unpredictable and weakness is typically in the hind end. If the foal was separated from the mare for the procedure, use caution when reintroducing the foal. A handler should be with the mare while the foal attempts to nurse initially.

### 3. Discussion

Anesthesia of the foal for minor surgical procedures should not be a scary process. Reviewing protocol procedures with your staff in the winter prior to foaling season is highly recommended. Being prepared is always the safest method when planning an anesthetic case—have drugs and emergency equipment ready. We are fortunate to have relatively safe sedative and anesthetic agents for horses. Accidental overdose of most of the commonly used sedatives and anesthetics is rarely fatal. If overdose does occur, reverse the drugs (if possible) and manage the clinical signs associated with the overdose (fluids, steroids, etc.).

### Acknowledgments

#### Declaration of Ethics

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The Author has no conflicts of interest.

### Reference and Footnotes


6. Versed, Roche Medical, Hertfordshire, United Kingdom.
7. Epinephrine, VetOne, Boise, ID 83705.
8. Triple Drip (guaifenesin, ketamine, xylazine) Guaifenesin, Rood and Riddle Veterinary Pharmacy, Lexington, KY 40511.
11. Acepromazine, VetOne, Boise, ID 83705.
How to Manage the Pain of Laminitis in the Field

Lori A. Bidwell, DVM, DACVAA

1. Introduction
Laminitis is one of the most frustrating and disappointing ailments in equine practice. In severe cases, budget concerns often result in the decision to euthanize. The delicate structures that support the entire body are affected, requiring a management plan that produces comfort but avoids hyperactivity. Aggressive treatment is required to minimize inflammation and produce an adequate level of comfort that maintains appetite and attitude.

2. Materials and Methods
Laminitis can be divided into phases of disease or grades of severity. Treatment for acute disease requires basic principles of care, and chronic disease requires owner, farrier, and veterinarian commitment. Immediate treatment of laminitis in the acute phase should include nonsteroidal anti-inflammatory drugs (phenylbutazone or flunixin meglumine), removing shoes, protecting the feet with purple podiatry pads or foam, and changing the footing to something deep and soft in the stall (sand is preferred). The author uses phenylbutazone dosing at 2 gm once daily for adult horses as a baseline treatment. An addition of omeprazole to protect the stomach is recommended, as many horses in the acute phase of laminitis have a decreased appetite. Horses that are intolerant to nonsteroidal anti-inflammatory drugs can be given Traumeel tablets, a homeopathic analgesic and anti-inflammatory medication (15 tablets for an adult horse twice daily). Traumeel can be purchased at most pharmacy and health food stores. Detomidine administered at 1.0–2.2 mcg/kg intramuscularly can be combined with butorphanol at 0.04–0.05 mg/kg subcutaneously. This combination can be dosed every 4–8 hours as needed over the initial 24–48 hour period. In addition, lidocaine patches can be cut to size and applied around the pastern and fetlock (1 patch per leg, 700-mg patches) and covered with a support bandage. Pain relief is typically visible within 30 minutes of applying the patches and wanes after 11 hours. Lidocaine patches should be changed every 12 hours as needed. The patches work locally rather than systemically. Blood levels of lidocaine were not detectable in a horse suffering from laminitis that had two patches applied every 12 hours for two weeks, but lidocaine was detected in urine. Sarapin or “Veggie Blocks” can be used to minimize pain. Typically, 2.5 ml Sarapin or P-Block is injected subcutaneously per site at the location of an abaxial block. An alternative for pain relief is the placement of a soaker-type perineural catheter subcutaneously along the branches of the digital nerve. Local anesthetics can be infused through the catheters for prolonged periods of time.
with a farrier or podiatrist is essential. Trimming the feet on a weekly basis and applying appropriate pads, wedges, or shoes should be organized as a joint effort with the farrier.

The patient’s comfort level should be evaluated on a daily basis during the initial week of onset of laminitis. Develop a simple pain scale by using attitude, appearance, appetite, mobility, heart rate, and gastrointestinal motility as indicators of pain intensity. Tailor the analgesic protocol on a daily basis using these parameters. Analgesics will not result in “too much comfort,” resulting in worsening of injury to laminae. Instead, analgesia is necessary to prevent long-term damage to the central nervous system and to allow adequate appetite.

Treating chronic laminitis pain involves developing a balance between budget restraints placed by the owner, analgesic options, and patient drug tolerance. Nonsteroidal anti-inflammatory drugs remain the standard of care. Gabapentin, methadone, and tramadol are additional options for long-term care. Gabapentin, an anticonvulsant, is used in human medicine for neuropathic pain and postneurological injury. The drug acts by quieting hyperexcitable nerves and is reported in humans to prevent the “tingling” feeling post-nerve injury. Although gabapentin does not produce analgesia alone in most patients, it allows other drugs to be more effective. Although pharmacokinetics studies of gabapentin in horses have not been completed, anecdotal dosing in horses is anywhere between 2.5–20 mg/kg orally twice daily. From the author’s experience, start with 2.5 mg/kg orally three times a day for the first day then back down to twice daily. Long-term dosing can be used and should not be discontinued without tapering the dosing regimen. Methadone (an opioid with mu receptor agonist and N-methyl-D-aspartate activity) can be used as a long-term treatment for chronic laminitis pain but is a Schedule II drug with the Drug Enforcement Administration. Therefore, dosing requires veterinary administration. The author has used 0.1 mg/kg orally twice daily of the 40-mg fast-dissolving tablets for 1–2 month durations in chronic cases with no clinical negative effects. Tramadol has shown limited effectiveness in horses but can be used as an alternative when a patient is refractory to other medications. Dosing should start at 5 mg/kg orally twice daily and can be increased to 10 mg/kg orally twice daily.1

### 3. Discussion

Every patient has a different response to pain. It is dangerous to think that every patient will respond the same way to analgesics. Be aggressive with treatment in the early phase of disease and find a balance with long-term care that is suited to each patient. If the owner is unable to commit to long-term care strategies, euthanasia is recommended early in the disease process rather than later.

#### Acknowledgments

**Declaration of Ethics**

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**Conflict of Interest**

The Author has no conflicts of interest.

#### Reference and Footnotes


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<td><strong>Step 1: Evaluate the patient</strong></td>
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<tr>
<td>Pain level: pain score scale of 1–10</td>
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<td>Understand owner expectations: return to full work? Pasture sound?</td>
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<td>Make a treatment plan with a schedule or humanely euthanize the horse</td>
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<td><strong>Step 2: Medications</strong></td>
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<tr>
<td>Medication</td>
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<tr>
<td>Type/Use</td>
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<td>NSAID: analgesic, anti-inflammatory</td>
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<td>Homeopathic, alternative to NSAIDs: anti-inflammatory, analgesic</td>
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<tr>
<td>Phenylbutazone</td>
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<td>Detomidine</td>
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<td>Lidocaine patches</td>
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<td>Opioid: analgesic</td>
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<td>Analgesic for neuropathic pain</td>
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<td>Analgesic</td>
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<td>2 mg orally once daily</td>
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<td>0.04–0.05 mg/kg SC every 4–6 hours as needed</td>
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<td>1–2 mg/kg IM, every 4–6 hours as needed</td>
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<td>700-mg patch cut to size, changed every 12 hours</td>
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<td>2.5 ml Sarapin at each site for abaxial nerve block</td>
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<td><strong>If significant pain or no response to NSAIDs</strong></td>
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<td>Detomidine</td>
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<td>Butorphanol</td>
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<td>Lidocaine patches</td>
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<td>Veggie or Sarapin blocks or soaker catheter</td>
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<td>15 tablets orally twice daily</td>
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<tr>
<td><strong>NSAID,</strong> nonsteroidal anti-inflammatory drug; <strong>IM,</strong> intramuscular; <strong>SC,</strong> subcutaneous.</td>
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How to Sedate and Anesthetize the Untouchable Horse

Nora Matthews, DVM, DACVAA

1. Introduction
Untouchable horses may vary from truly feral horses in open range areas to unhandled youngsters in the clinic or pasture environment. All are potentially dangerous and require careful assessment of the patient as well as assessment of what facilities and what personnel are available. Extreme caution should be used to prevent injuries to both handlers and horses. The veterinarian must think carefully about what they are taking on, and whether they are equipped for success before starting.

2. Feral Horses in Open Range Where Corral, Fenced Areas or Chutes are not Available
These situations will usually require dart administration of drugs and is beyond the scope of this talk, although some references have been provided.1–4

3. Nondomesticated or Minimally Handled Horses Where Restraint Is Available (e.g., Cattle or Roping Chute)
Many horses that have not been handled may still be fairly familiar with being around humans. For example, rodeo bucking horses are used to standing in chutes and can be injected intravenously (IV) or intramuscularly (IM) through the chute. This is also true for horses at Bureau of Land Management facilities which are run through chutes and anesthetized for castration. They may also be used to some restraint such as being haltered. The key is that appropriate dosages of drugs are given, preferably on the first attempt. Unfortunately, the horse’s weight usually has to be estimated visually and perhaps corrected for body condition. If the patient is in extremely poor body condition it may be better to postpone whatever procedure is planned until that patient is in better shape. Obesity in these patients is much less common and the author would not adjust drug dosage for the overweight horse. The author’s experience agrees with a previous report; usual premedication doses of \( \alpha_2 \) agonists should be 2 to 3 times standard dose for IV administration and higher for IM administration. The author recommends 3 to 5 mg/kg xylazine when given IM and 0.04 to 0.06 mg/kg detomidine when given IM. Induction with higher-than-normal doses of ketamine (2–4 mg/kg IV) should be used and diazepam (0.1 mg/kg, IV) is helpful to increase muscle relaxation and duration of anesthesia. Triple drip can be used for maintenance—the author typically uses a mixture of 500 mg xylazine with 2000 mg ketamine in 1 L of 5% guaifenesin. For longer procedures these horses can be intubated and maintained with inhalant anesthesia, as one would...
do for any other horse. Recovery usually occurs back in the patient’s stall or corral; if the horse has been moved back from the induction area, it must be moved back to a suitable area for recovery. Covering the horse’s eyes with a towel may be helpful as the patient is left to self recover. Manual assistance in a minimally handled horse is probably not productive; even if ropes would help in recovery, the stimulus of trying to get them off might be dangerous. The addition of appropriate analgesics, additional sedatives, and/or local blocks will help produce a better recovery.

If there is a history of the patient (or relatives) being “refractory” to ketamine it is wise to start with other drugs. Sometimes this history is not known and the veterinarian may be faced with a horse that has received appropriate sedation and then has not become anesthetized (or only briefly anesthetized) with a full dose of ketamine. If the procedure is elective, the author would advise quitting for the day and planning another approach. In the past, the approach for these patients was to use thiopental, usually mixed with guaifenesin, for induction and maintenance of anesthesia. Since thiopental is no longer available in the United States, the best option may be to use tiletamine-zolazepam. This drug can be given IM (by pole syringe if necessary) or IV (see Magdalena et al and Matthews et al for dosages). Recoveries from tiletamine-zolazepam may be longer and rougher and sedation in recovery may be necessary. Although the component drugs in tiletamine-zolazepam are very similar to diazepam and ketamine, the potency of both drugs is greater, which is likely why they are more effective for the “refractory” patient. Combinations using propofol have been used for ketamine-resistant horses, but the incidence of apnea is extremely high when using propofol in horses. Equipment for ventilation should be available and some experience with the drug is required.

4. Uneducated or Needle-Shy Horses
These may be weanlings to 2-year-olds who have not been handled much yet (think, halted for the first time today and transported to your clinic for castration). The author is very quick to get out the detomidine gel for oral administration. Many of these horses will have been paste wormed and will accept oral gel. Although the detomidine gel label recommends that the product be placed under the tongue, the author’s experience with the gel is that it sticks quite nicely to gums and oral mucosa so if you get it into the mouth most of it will be well absorbed. It is imperative to wait a full 40 minutes for optimal sedation (using the label dose); then it is possible to place an IV catheter or give IV premedications for anesthesia. Although this is off-label use of the product (i.e., as a premedication for anesthesia), the author thinks it is safer for all involved than to get the horse very excited. In the author’s experience it has been more dependable sedation than IM administration. Depending on how much time has elapsed since oral drug is given, the author may “top up” with additional α₂ or not, depending on how sedate the horse looks. The goal is trying to get the horse in a “head to the knees” position before administering the induction drugs. The author’s usual “top-up” dose is ¼–½ of my usual dose. Then the author uses standard induction doses of ketamine with diazepam for induction, and maintains with triple drip or inhalant anesthesia depending on expected duration of the procedure. Recovery may be slightly longer, depending on the length of the procedure, but is not greatly extended by the oral detomidine, probably because of the initial 40-minute delay after oral administration.

5. Discussion and Summary
All horses are dangerous and all equine anesthesia is inherently dangerous. Although other techniques and drug combinations that might be used for unhandled horses exist, the author has had success with these combinations and techniques.

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

Conflict of Interest
The Author has no conflicts of interest.

References and Footnotes

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Alternative Methods of Equine Euthanasia

Tracy A. Turner, DVM, DACVS, DACVSMR

Inducing anesthesia prior to euthanasia offers an easier method of control. Adjunctive techniques using intravenous potassium or magnesium salts, intracardiac potassium chloride, or intrathecal lidocaine offer methods that work well and are more environmentally safe than barbiturates. Pithing and exsanguination are also environmentally safer but may not be as aesthetically acceptable as the other methods. Author’s address: Turner Equine Sports Medicine and Surgery, 10777 110th St., Stillwater, MN 55082; e-mail: tracyturner1953@gmail.com. © 2018 AAEP.

1. Introduction

The term “euthanasia” is derived from the Greek and means “good death.” The term is usually used to describe ending the life of an individual animal in a way that minimizes or eliminates pain and distress. A good death is tantamount to the humane termination of an animal’s life. In the context of AVMA Guidelines, the veterinarian’s duty in performing euthanasia includes, but is not limited to, his or her ability to induce death in a manner that is in accord with an animal’s interest and/or because it is a matter of welfare, and the use of humane techniques to induce the most rapid, painless, and distress-free death possible. These conditions, although separate, are not mutually exclusive and are codependent.

In regard to horses, there are three acceptable methods; overdose of intravenous barbiturate, penetrating captive bolt, and gunshot. Penetrating captive bolt and gunshot euthanasia should only be used by well-trained personnel who are regularly monitored to ensure proficiency, and firearms must be well maintained. Appropriate restraint is required for application of the penetrating captive bolt and special care should be taken to ensure that personnel are not injured by ricochet from free bullets. Unfortunately, veterinarians are not routinely trained with these two methods. Barbiturates present other problems; disposal of remains must be carried out promptly through commercial rendering, on-farm burial, incineration or cremation, direct haul to a solid waste landfill, or biodigestion. This will help prevent exposure of wildlife and domestic animals to potentially toxic barbiturate residues. Disposal of remains must be conducted in accordance with all federal, state, and local regulations. Recently, rendering facilities have refused equine carcasses due to the barbiturate. The same is true for landfills and even composting due to the worry of soil and water contamination with barbiturates. These drugs invoke legal responsibilities for veterinarians and animal owners to properly dispose of animal remains after death. Animal remains containing pentobarbital are potentially poisonous for scavenging wildlife, including birds (e.g., bald and golden eagles, vultures, hawk species, gulls, crows, ravens), carnivorous mammals (e.g., bears, martens, fishers, foxes, lynxes, bobcats, cougars), and domestic dogs. Federal laws protecting many of these species apply to...
secondary poisoning from animal remains containing pentobarbital. The Migratory Bird Treaty Act, the Endangered Species Act, and the Bald and Golden Eagle Protection Act may carry civil and criminal penalties, with fines in civil cases up to $25,000 and in criminal cases up to $500,000 and incarceration for up to 2 years. Serious repercussions may occur when veterinary health professionals who should be well-informed about the necessity for proper disposal of animal remains fail to provide it, or fail to inform their clients how to provide it, whether there was intent to cause harm or not.1

2. Alternative Methods of Euthanasia
In order to determine if an alternative method of euthanasia is acceptable, the AVMA considers several factors: ability to induce loss of consciousness and death with a minimum of pain and distress; time required to induce loss of consciousness; reliability; safety of personnel; irreversibility; compatibility with intended animal use and purpose; documented emotional effect on observers or operators; compatibility with subsequent evaluation, examination, or use of tissue; drug availability and human abuse potential; compatibility with species, age, and health status; ability to maintain equipment in proper working order; safety for predators or scavengers should the animal's remains be consumed; legal requirements; and environmental impacts of the method or disposition of the animal's remains.

The AVMA Guidelines classify euthanasia methods as acceptable, acceptable with conditions, and unacceptable. Acceptable methods are those that consistently produce a humane death when used as the sole means of euthanasia. Methods acceptable with conditions are those techniques that may require certain conditions to be met to consistently produce humane death, may have greater potential for operator error or safety hazard, are not well documented in the scientific literature, or may require a secondary method to ensure death. Methods acceptable with conditions are equivalent to acceptable methods when all criteria for application of a method can be met. Unacceptable techniques are those methods deemed inhumane under any conditions or that the Panel on Euthanasia found posed a substantial risk to the human applying the technique.

The Panel on Euthanasia recognizes there will be less-than-perfect situations in which a method of euthanasia that is listed as acceptable or acceptable with conditions may not be possible, and a method or agent that is the best under the circumstances will need to be applied.1

A key to understanding appropriate euthanasia techniques is understanding conscious versus unconscious. Unconsciousness may be defined as loss of individual awareness that occurs when the brain's ability to integrate information is blocked or disrupted. In humans, the onset of anesthetic-induced unconsciousness has been functionally defined by the loss of an appropriate response to verbal command and in animals, by loss of the righting reflex.5,6 This definition, introduced with the discovery of general anesthesia more than 160 years ago, is still useful because it is an easily observable, integrated whole-animal response.

Anesthetics produce unconsciousness either by preventing integration or by reducing information received by the cerebral cortex or equivalent structure(s). Furthermore, the abrupt loss of consciousness that occurs at a critical concentration of anesthetic implies that the integrated repertoire of neural states underlying consciousness may collapse nonlinearly.7 Data from different species suggest that memory and awareness are abolished with less than half the concentration required to abolish movement. Thus, an anesthetic state (unconsciousness and amnesia) can be produced at concentrations of anesthetic that do not prevent physical movements.6

There are several adjunctive techniques that are useful under general anesthesia. Injecting a solution of potassium chloride, magnesium chloride, or magnesium sulfate intravenously or intracardially are simple techniques. In addition, exsanguination or pithing may be performed under general anesthesia. A new technique uses lidocaine injected intrathecally to cause death.

3. Techniques
It is the author’s opinion that a simpler, safer, and more aesthetic method of euthanasia is to induce anesthesia first with intravenous xylazine (1.1 mg/kg) to induce heavy sedation followed by intravenous ketamine (2.2 mg/kg). This combination in the author’s experience reliably provides 10 minutes of anesthesia that is plenty of time to accomplish any of the following adjunctive measures. In addition, there is evidence that drug residues after use of these drugs are safe.8

Potassium chloride may be administered by an intravenous or intracardiac route. The potassium ion is cardiotoxic, and rapid IV or intracardiac administration of 1–2 mmol/kg (0.5–0.9 mmol/lb) of body weight (1–2 mEq K+ /kg; 75–150 mg/kg [34.1–68.2 mg/lb] of potassium chloride) will cause cardiac arrest.9 Practically, super saturate Lile salt into a water solution and administer to effect. Likewise, magnesium salts can be put into solution and administered intravenously.

An advantage of these drugs is that potassium chloride and magnesium salts are not controlled substances and are easily acquired, transported, and mixed in the field.1 Potassium chloride and magnesium salt solutions, when administered to an unconscious equid, result in remains that are potentially less toxic for scavengers and predators and may be a good choice in cases where proper disposal of animal remains (e.g., rendering, incineration) is impossible or impractical.10,11
Disadvantages of these drugs are they may cause muscle spasms shortly after injection. Potassium chloride and magnesium salt solutions are not approved by the Food and Drug Administration for use as euthanasia agents. Saturated solutions are required to obtain suitable concentrations for rapid injection into equids.

A recently described technique is the use of intrathecal lidocaine during intravenous anesthesia.

After induction of anesthesia, an area over the atlanto-occipital space would be prepared enough (clipped) to allow for the identification of landmarks. The horse’s head is flexed to open the atlanto-occipital space. A 6-inch 18-gauge needle is inserted just on a line along the cranial edge of the atlas and on the midline. The needle is directed toward the lower jaw and advanced until the dura is penetrated. Sixty milliliters of cerebrospinal fluid is removed and 60 ml of 2% lidocaine hydrochloride is administered within 30 seconds.12

The main advantage of this technique is all drugs are readily available and relatively inexpensive. The animal remains of this technique would be less toxic to the environment compared with using barbiturates.

The main disadvantage of this technique is it requires specific skills. Also, the technique is slightly slower in causing cessation of respiratory, cardiovascular, and neurologic function than barbiturate euthanasia.

A variation of this technique is to pith the horse after induction of anesthesia. The operator manipulates the pithing tool through the atlanto-occipital space to substantially destroy both brainstem and spinal cord tissue.4

The final technique involves exsanguination.1 Because anxiety is associated with extreme hypovolemia, this should be performed only under general anesthesia. Exsanguination can be performed by opening the throat; however, this is not aesthetic. As a result, a per rectal technique may be more appealing. A knife or scalpel is introduced per rectum. The caudal aorta is identified and cut.

4. Conclusion

Acceptable methods of equine euthanasia have problems. Barbiturates create environmental issues and disposal problems. Gunshot and the use of penetrating captive bolt require special training. Adjunctive techniques performed after inducing anesthesia offer a simple alternative that require skills more typical of veterinary training and pose a lower risk of environmental toxicity.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Effect of Intravenous Catheter Placement on Arytenoid Function in Thoroughbred Sales Yearlings

Peter R. Morresey, BVSc, MVM, DACT, DACVIM*; Rolf Embertson, DVM, DACVS; Scott Pierce, DVM; Mary Keen, BS; and Pouya Dini, DVM, PhD

The side of placement of intravenous catheters in juveniles did not affect arytenoid function in a study of endoscopic evaluation of sales Thoroughbred yearlings. Clinicians should not hold preconceived notions as to the potentially deleterious effects of jugular catheter placement arising from the side of insertion. Authors’ addresses: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580 (Morresey, Embertson, Pierce); University of Kentucky College of Pharmacy, Lexington, KY 40536 (Keen); University of Kentucky Gluck Equine Research Center, Lexington, KY 40546 (Dini); e-mail: pmorresey@roodandriddle.com. * Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Intravenous catheter placement into the jugular vein of the horse is a routine procedure at all levels of clinical practice. Complications are not commonplace. However, given the proximity of the jugular vein to the recurrent laryngeal nerve pathway, any problems that arise (cellulitis, jugular thrombophlebitis) may compromise the integrity of the recurrent laryngeal nerve, with the potential to affect laryngeal function and subsequently result in an impediment to performance. However, anecdotal information and clinician opinion factors into decisions regarding jugular catheter placement and its potential for deleterious effects on future arytenoid function even in the absence of known catheter-related pathology. Potential effects on arytenoid function are of both clinical and economic importance, as in a previous endoscopic study of Thoroughbred sales yearlings, those with compromised arytenoid function had reduced career racing performance at two to four years of age as measured by number of starts and earnings. The objective of this study was to determine if previous jugular catheter placement, including consideration of side and duration, affected arytenoid function in Thoroughbred yearlings when evaluated endoscopically prior to sale by auction.

2. Relevant Anatomy

The course of the recurrent laryngeal nerves has been reviewed. The right recurrent laryngeal nerve branches from the vagus at the level of the first intercostal space, passes medially around the right subclavian or costocervical artery, then associates with the lateral tracheal wall. The nerve then travels cranially with the trachea and becomes situated on its dorsolateral aspect in the...
mid-cervical region, continuing rostrally to the larynx where further division occurs prior to innervation of the laryngeal musculature. The left recurrent laryngeal nerve branches from the left vagus at the level of the base of the heart. This location is approximately 25–30 cm caudal to the equivalent branching point of the right recurrent laryngeal nerve. It divides into two branches, which travel medially around the aorta and ligamentum arteriosum before reaching the trachea. The smaller branch briefly associates with the sympathetic nerve before rejoining the main branch, and the left recurrent laryngeal nerve then follows a similar course rostrally to the larynx as described above for the right recurrent laryngeal nerve. The cervical transit of the recurrent laryngeal nerves therefore places them in close proximity to the clinically accessed vascular structures of the neck.

3. Materials and Methods

Case Selection
Upper airway endoscopy reports generated at the time of assessment for sale by auction at a major center of Thoroughbred horse sales were retrospectively accessed. To conduct the examination, yearling horses were unsedated and restrained in a stall by nose twitch or on occasion lip chain. The endoscope was introduced to the right nostril as far as the nasopharynx. Arytenoid function was assessed both at rest and following swallowing and during occlusion of the nares. The study population included horses judged to be normal or to have arytenoid dysfunction at examination. The years 2006–2011 were included.

Record Review
Data obtained from reports with respect to horses included age, date of intravenous catheter placement, type of intravenous catheter, side and duration of intravenous catheter placement, and date of upper airway endoscopy. Where recorded, either over-the-needle polypropylene or over-the-wire polyurethane intravenous catheters were identified. With respect to endoscopy findings, date of endoscopy, scope numerical grade (I–IV), scope letter grade (A, B, AB, where recorded), and side of diminished laryngeal function (L, R) were obtained.

Scope Grading System
Grades I–IV were assigned based upon endoscopic findings (Table 1). Within numerical grades II and III, a subclassification was also recorded. The arytenoid grade scoring system has been previously reported and is comparable to the modified Hae-meyer grading scale.

Statistical Analysis
The relationship between upper respiratory tract scope grades (I–IV) and side of catheter (left and right) was determined using ordinal logistic regression. Side of catheter, duration of having catheter in the vein, the duration from placement of catheter and day of scoping, and interaction between these factors were set as the effects. Statistical analysis was performed in JMP 13 software.

Power analysis was performed on the results to evaluate whether the study was underpowered or whether the sample size per group was under the required number to detect a difference between two proportions by using G*Power software version 3.1.9.3. Based on the probability of cases with the score above II for each side of catheter placement (p1 = 0.14 and p2 = 0.07), 237 samples per group was sufficient to show statistical differences between the two groups (power = 0.8 and α = 0.05).

4. Results
Age at intravenous catheter placement ranged from neonates to yearlings. Duration of intravenous catheter placement (d, whole days) ranged 0–28

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
<th>Subclassification</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Arytenoid cartilage abduction is <strong>synchronous</strong>, symmetrical. Full abduction achieved and maintained.</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>Arytenoid cartilage abduction is <strong>asynchronous</strong> and/or asymmetrical. Full abduction achieved and maintained.</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Arytenoid cartilage abduction is asynchronous and/or asymmetrical. <strong>Full abduction is not achieved and maintained.</strong></td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td><strong>Complete immobility</strong> of arytenoid cartilages</td>
<td></td>
</tr>
</tbody>
</table>

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days (median 1d, mean 1.63d, sd 2.34d). Time between intravenous catheter placement and endoscopic examination ranged 1–595 days (median 182d, mean 251d, sd 159d).

Of the 1145 horses reported, all had left-sided arytenoid cartilage dysfunction, with no right-sided asymmetry reported. Following endoscopic examination, the placement of a jugular catheter (Groups YES and NO) when compared to endoscopic grade (I–IV) had no effect on endoscopic grade (Table 2).

Of the 1145 records obtained, 444 horses had left-sided intravenous catheter placement, 275 horses had right-sided intravenous jugular catheter placement, and 424 had no report of jugular catheterization. Of these, 444 left-sided placement horses had complete useable data and 273 right-sided placement horses had complete useable data. The remaining reports were missing essential data and were excluded from further analysis. For each numerical grade, the letter grade has been discarded and results grouped for analysis. Endoscope grade recorded related to the side of catheter placement is displayed in Table 2. No effects were attributable to side of jugular catheter placement. Duration of catheter placement did not affect endoscopic grade, and the interaction of time and side of catheter placement had no effect.

### 5. Discussion

Results of this retrospective study suggest that placement of a jugular intravenous catheter, duration of catheter placement, and side of catheter placement do not affect subsequent endoscopic evaluation of arytenoid function.

The placement of an intravenous catheter has been associated with the occurrence of thrombophlebitis in a number of previous studies. The catheter may be a nidus for clot formation, the endothelium can be abraded by the distal catheter, and localized venous stagnation may occur. Duration of placement has also been found positively associated with thrombophlebitis in one study, and although duration was not associated with scope grading in this study, the occurrence of thrombophlebitis could not be determined. Although thrombophlebitis is anecdotally considered a risk factor, records assessed in this study neither recorded nor implied thrombophlebitis in horses that had laryngeal dysfunction, either with or without a known history of catheter placement.

A wide range of surgical and medical indications for intravenous catheter placement commonplace in clinical equine practice were recovered in this study by matching sale endoscopy records to known hospital interventions. These include routine surgical orthopedic procedures to correct conformation (periosteal elevation, transphyseal screw placement/removal), fracture repair, joint sepsis, joint bone chip removal, and scintigraphy. Emergency surgical soft tissue indications included laceration repair, puncture wound management, osteomyelitis, hernia repair, and colic. Medical indications often involved a septic process, including omphalophlebitis, pneumonia, infectious diarrhea (salmonellosis, clostridiosis), and cellulitis. Nonseptic processes resulting in intravenous catheter placement included impaction colic, ileus, enteritis, and perinatal asphyxia syndrome of neonatal foals. The presence of sepsis is a risk factor for the occurrence of a hypercoagulable state, increasing the possibility of thrombophlebitis.

Of note, not a single occurrence of right-sided laryngeal hemiplegia was reported in the population assessed. This compares with a previous report of laryngeal hemiplegia in 127 horses in which all cases involved the left side; however, 3 horses had bilateral dysfunction. Reports of right-sided laryngeal hemiplegia do exist. The reduced incidence of right-sided laryngeal hemiplegia, when compared with that of the left side, is compatible with the theory that the right recurrent laryngeal nerve being physically shorter than the left is less likely to undergo degenerative change, and, hence, right-sided laryngeal function is less likely to be compromised.

When present, precipitating conditions for laryngeal dysfunction include guttural pouch mycosis, perivascular irritant injection, trauma, plant intoxications, and chemical toxicities. There is, however, no universally accepted theory as to the cause of idiopathic laryngeal hemiplegia. A hereditary component has been suggested, with an extrinsic factor precipitating clinical disease.

This study did not differentiate endoscopy reports based on sex and body size. Overall occurrence of impaired arytenoid abduction in horses has been

### Table 2. Endoscopic Grade in Relation to Intravenous Catheter Placement and Side of Insertion

<table>
<thead>
<tr>
<th>Endoscopic grade</th>
<th>Total</th>
<th>I</th>
<th>II</th>
<th>III</th>
<th>IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jugular catheter placement?</td>
<td>Yes</td>
<td>713</td>
<td>30.5% (217)</td>
<td>68.4% (488)</td>
<td>0.8% (6)</td>
</tr>
<tr>
<td></td>
<td>No</td>
<td>424</td>
<td>28.5% (121)</td>
<td>69.6% (295)</td>
<td>0.5% (2)</td>
</tr>
<tr>
<td>Side of placement of jugular catheter</td>
<td>Left</td>
<td>440</td>
<td>31.6% (139)</td>
<td>67% (295)</td>
<td>0.9% (4)</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>273</td>
<td>29.3% (80)</td>
<td>70.3% (192)</td>
<td>0.4% (1)</td>
</tr>
</tbody>
</table>

Numbers in each category are in parentheses.
previously variably reported, 1.8%, 13 3.3%,14 and 8.3%.15 Some authors have suggested the condition to be higher in males16 and more prevalent in longer necked horses.17

Consideration should be given to the possibility that the onset of laryngeal nerve degeneration may be delayed and resulting arytenoid cartilage dysfunction develops at greater ages than represented in the study population. Additional research is therefore necessary to evaluate older horses for any relationship between jugular vein catheterization and endoscopic evidence of arytenoid dysfunction.

In conclusion, the act of placement, side of insertion, and duration of residence of previous intravenous jugular catheters had no effect on arytenoid function in a population of sales yearlings. Clinicians should therefore determine side of jugular catheter placement considering familiarity of technique and physical disposition of the horse, not with preconceived notions of potential negative laryngeal functional sequelae.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflicts of Interest
The Authors have no conflicts of interest.

References and Footnotes

How to Place an Epidural Catheter for Long-Term Analgesia with Morphine/Detomidine in Horses

Danica Wolkowski, BSc, DVM

1. Introduction
Pain has been proven to suppress immune response, trigger inflammation, delay healing, and increase the likelihood of intensive medical treatment in equine patients. Controlling pain is not only of utmost importance for the welfare of our patients, but also significantly decreases morbidity and the cost of patient care. Conventionally, pain in horses has been treated with nonsteroidal anti-inflammatory drugs (NSAIDs) whose use at high doses or for long periods is associated with side effects such as oral, gastric, and duodenal ulceration, colonic ulceration and necrosis, renal crest necrosis, and hematologic changes.

Epidural administration of opioid and α-2 agonist drugs has been demonstrated to provide significant analgesia to horses. The aim of administering analgesics into the epidural space is to provide pain relief by using selective spinal-mediated analgesia, thus bypassing systemic effects of intravenous or orally administered analgesics such as NSAIDs and decreasing morbidity associated with analgesic therapy. When administered intrathecally, opioids and α-2 agonists diffuse into the cerebrospinal fluid and move into the dorsal horn where μ-opioid and α-2 receptors are abundant. Through this mechanism, drugs such as morphine and detomidine can provide analgesia without causing significant adverse effects. In addition, epidurally administered morphine has been shown to provide better analgesia for patients undergoing gastointestinal (GI) surgery when compared with systemically delivered opioids. By placing an epidural catheter, analgesics acting at specific receptors in the spinal cord can be administered correctly and conveniently in patients suffering from caudal abdomen, pelvic, and pelvic limb pain.

The goal of administering these agents intrathecally is to provide adequate analgesia without affecting motor function of the pelvic limbs or causing significant systemic effects. This paper will aim to highlight the indications, placement, use, and management of epidural catheters in treating pain in the horse.

Any hospitalized patient requiring preoperative, postoperative, or ongoing analgesia in the region of the caudal abdomen, pelvic limb, tail, perineum, rectum, distal colon, bladder, and pelvic reproductive organs.
2. Materials and Methods

Landmarks (Fig. 1)
The epidural catheter is placed at the first coccygeal interspace (Co1–Co2) in horses. This region can be located by moving the tail up and down and palpating the first moveable joint caudal to the sacrum. Additionally, this location is commonly in a midline depression approximately 5 cm from the tail head.

Materials (Fig. 2A)
1. 5% Chlorhexidine scrub
2. 99% Alcohol
3. Sterile gloves
4. Clippers
5. 2% lidocaine
6. Sterile 0.9% saline
7. Epidural catheter kit* including:
   A. Epidural catheter with wire stylet
      a. 20 gauge, 90 cm
      b. Closed end with side holes
   B. Tuohy introducer needle
   C. Loss of Resistance syringe
   D. Catheter adapter\(^b\)
   E. Filter
   F. Injection adapter (PRN)
8. Bandage tape
9. Blade
10. Drape
11. Tape measure
12. Non-absorbable suture or stapler

Patient Preparation
Prior to preparation of the epidural site, the horse must be adequately sedated to allow for the procedure. Measure the space from the sacrocaudal vertebrae to lumbosacral vertebrae. This is the distance you will advance your catheter past the tip of the Tuohy needle. A 5-inch × 5-inch square can be clipped on midline, centered at the Co1–Co2 space.

Fig. 1. The sacral coccygeal joint of the horse. The red arrow indicates the site at which the Tuohy needle will be placed.

Fig. 2. A. Layout of supplies required for epidural catheter placement. B. Clipped epidural catheter site. C. Palpation of the first moveable coccygeal joint space with assistant raising the tail. D. Placement of Tuohy needle at 45° angle.
An initial preparation of the clipped area is performed and 3 mL of 2% lidocaine is administered in the soft tissues at the site of the epidural. A needle is inserted under the skin and lidocaine is injected as the needle is slowly removed. Following the local block, a standard surgical preparation of the region is performed.

Placement
Personnel performing this procedure must follow strict aseptic technique during the placement of the epidural catheter.

1. Sterile field is secured and sterile supplies are opened into sterile field.
   a. Epidural catheter pack can also be used and will be opened before sterile gloves are put on.
2. Place a fenestrated sterile drape over the surgically prepped epidural site.
3. The epidural site is palpated and located with the index finger of the nondominant hand, opposite to the hand placing the catheter (Fig. 2C).
4. The Tuohy spinal needle is inserted at midline toward the epidural space of Co1–Co2 by placing the needle at an angle of 45° to horizontal with the beveled edge facing craniodorsally (Fig. 2D).
5. The needle is advanced until contact is made with bone. While the needle is advancing, several pops may be felt as different facial planes are penetrated. Once the bone is contacted, the needle is withdrawn slightly, directly cranially, and placed in the epidural space. Remove the stylet of the Tuohy needle.
6. Placement can be confirmed by A) the Loss of Resistance or B) Hanging Drop technique.
   a. Draw room air into a sterile Loss of Resistance syringe until it is half full, attach it to the hub of the Tuohy needle, and attempt to gently depress the plunger. If placement is correct, resistance will be minimal and the plunger will not change position when pressure is removed. If resistance is apparent or the plunger bounces back when pressure is removed, the needle can be withdrawn slightly and tested again following the same procedure.
   b. After the Tuohy stylet is removed, the needle can be filled with sterile saline so that a drop of saline sits at the hub of the needle. When the epidural space is entered, the drop is pulled into the space and disappears.
   c. Note: After two to three unsuccessful attempts, the needle should be removed and the procedure repeated beginning at step 3. Do not attempt this procedure more than two times.
7. Place the catheter with guide wire into the hub of the Tuohy needle and gently advance it to the tip of the needle. Slight resistance will be met as the catheter is moved past the tip of the needle.
8. Continue advancing the catheter past the tip of the Tuohy needle the distance measured during patient preparation and slowly remove the catheter guide wire and the Tuohy needle, ensuring that the catheter does not move.
9. Insert the external catheter tip into the injection adapter (Fig. 3A) until resistance is met, withdraw the catheter slightly and tighten the hub (Fig. 3B).
10. The luer attachment of the filter is attached to the hub of the catheter adapter (Fig. 3C).
11. Confirm catheter placement by injecting 5 mL of 0.9% sterile saline into the filter port and through the catheter. Resistance should be felt, but as long as saline continues to flow, then placement can be verified.
12. Place a catheter adapter on the injection port to seal the system.

Securing the Catheter
Multiple methods are listed below:

1. Securing options
   a. Apply a tape butterfly to the catheter at the level of entrance into the skin and staple or suture the butterfly to the patient. Apply another butterfly to the filter and staple or suture to the patient.
   b. Suture the catheter to the skin where it exits and apply a Chinese finger trap (Fig. 4A).
2. Place clear plastic or a bandage (Elastoplast works well) over the site to ensure accidental removal or contamination does not occur (Fig. 4B).

Use
The injection port should be cleaned with an antimicrobial swab prior to use. Analgesics can be infused slowly over 15 to 20 minutes.

Dosages of analgesic drugs to be administered epidurally are as follows: Morphine: 0.2 mg/kg or 0.1 to 0.2 mg/kg plus detomidine: 30 ug/kg every 12 hours. The analgesics can be administered with a total of 10 mL of sterile saline, and followed by a flush of 5 mL sterile saline to clear the analgesics from the catheter. Moreover, a variety of other drugs and drug dosages can be found in the cited literature.

Epidural catheters can stay in place for up to 2 weeks with no observable adverse effects.

3. Discussion
The use of indwelling epidural catheters in horses to administer analgesic agents is an excellent adjunct to conventional systemic therapy in practice.
The benefits of using this modality are abundant. Morphine/detomidine epidurals have been associated with fewer adverse effects when compared with their systemically administered counterparts. Moreover, the combination of epidural morphine and detomidine has been reported to provide profound analgesia, begin rapidly following administration, and last for up to 13 hours. Systemically administered morphine has previously been linked to decreased GI motility, but research has shown that this phenomenon is not a sequela to epidurally administered morphine. Intravenous detomidine causes deep sedation; this effect can be appreciated at high doses administered intrathecally but is less frequent at the suggested dose of 30 ug/kg. Finally, once the catheter is placed, analgesics can be conveniently and easily administered as needed in the correct location.

While there are many benefits to this approach, and it has been proven as a safer modality compared to systemic administration of the same drugs, it is not without some risk that the epidural catheter is placed and pharmacologic agents are administered. There have been a small number of cases reported in the literature that describe mild to severe pruritus observed after administering epidural morphine. However, in multiple studies adverse effects of epidural morphine were studied, and no horses developed pruritus or any significant unfavorable effects. The major limitations to this apparatus are the risk of infection and difficulty with placement of the epidural catheter until comfort with the procedure has been established. Preferably, epidural catheters should be placed in a hospital setting where monitoring and cleanliness are maintained. Another noteworthy adverse effect is the potential of hind limb ataxia and paralysis when fluid volumes greater than 20 mL are injected into the epidural space with resulting mechanical compression of the nerves.

There is data suggesting the use of many other agents to provide analgesia via epidural catheter.
Notably, it is important to understand that the administration of local anesthetics for the purpose of long-term analgesia in the pelvic limb is contraindicated in horses. Due to the profound ataxia and paralysis that local anesthetics can cause, they are not appropriate to administer continuously through an epidural catheter due to the risk of injury to the horse and personnel. Tramadol at a dose of 1 mg/kg has been shown to provide significant analgesia but is shorter in duration compared with morphine. Furthermore, buprenorphine (5 ug/kg) and detomidine (30 ug/kg) administered epidurally to horses were found to provide results that were not significantly different from morphine and detomidine administration. Hydromorphone (0.04 mg/kg) has also been studied as an epidural analgesic in horses and provided moderate pain relief with no significant ataxia or sedation. Many modes exist for relieving pain by intrathecal administration in horses.

The usefulness of this procedure has arisen when managing patients with injuries or conditions associated with severe pain and long healing times. It has also been reported that this method of providing analgesia works well if placed preoperatively to provide analgesia during surgery and throughout the postoperative period for procedures assumed to be painful. Furthermore, this technique has been used to provide relief from visceral pain in equine patients. There are many applications and potential pharmaceutical agents to use by intrathecal administration. Given the extent of scientific research on its efficacy and safety margins, epidural catheter analgesia can be considered an excellent therapy in providing pain relief to equine patients.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of Veterinary Medical Ethics of the AVMA.
Comparison of Xylazine and Detomidine in Combination with Midazolam/Ketamine for Field Castration in Quarter Horses

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Detomidine can be used as a premedication with midazolam/ketamine for field anesthesia and may offer an advantage over xylazine in fractious horses or where minimal assistance is available for the practitioner. Authors’ addresses: Iron Horse Equine Medical & Surgical Services, Elizabeth, CO 80107 (Smith); Colorado State University Veterinary Teaching Hospital, Fort Collins, CO 80525 (Bass, Damone, Mama, Rao); e-mail: drsmith@ironhorseequine.net. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
The ideal field anesthetic protocol for castration will offer an adequate duration and depth of anesthesia using a single injection without compromising safety or recovery quality. The objective of this study was to compare intravenous (IV) xylazine and detomidine as sedatives in combination with midazolam and ketamine for induction of anesthesia in horses undergoing field castration.

2. Materials and Methods
Fifty-two male Quarter Horses were randomly assigned to receive xylazine (group X) (1.1 mg/kg) or detomidine (group D) (0.03 mg/kg) as premedication with midazolam (0.05 mg/kg) and ketamine (2.2 mg/kg) anesthesia. Using simple descriptive scales, quality of sedation, induction, surgical conditions, and recovery were scored by blinded observers. Induction, surgery, recovery time, and time from induction to standing were recorded.

3. Results
Group D had better scores for sedation ($P = .05$) and surgical conditions ($P = .0084$) and was less likely to require maintenance doses of ketamine ($P = .0049$). Recovery time ($P = .001$) and time from induction to standing ($P = .0003$) were longer for group D. Induction and recoveries were uneventful with no significant differences between groups ($P = .95$ and $P = .35$, respectively).

4. Discussion
Detomidine as compared with xylazine as premedication results in good-quality sedation and surgical conditions and prolonged surgical plane of anesthesia, without significant differences in induction or recovery quality.
Acknowledgments

All protocols were approved by the Institutional Animal Care and Use Committee at the Authors' teaching university.

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Conflict of Interest

The Authors have no conflicts of interest.
Building Better Teams: How to Adapt and Change Your Leadership to Improve Employee Accountability and Engagement

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1. Introduction
If you have ever thought, “Why can’t everyone just come to work, do their job and be happy?” then you are not alone! High levels of productivity and team harmony are two of the most desired aspects of a good work place. Unfortunately, successful teams do not just magically happen. But, with effective leadership communications, veterinary practice managers and owners can improve team performance and create an environment where everyone is excited to come to work. Let us take a look at some communications and action steps that help practice leaders get the team they want.

2. Understanding Employee Motivation
Before we look at specific communications that improve team performance, it is important to understand what motivates employees. When employees have a less than stellar job performance, there is a tendency to label them as not being motivated in their job. This label often equates to a negative judgement about the person’s job performance and value to the practice. Before you go down this path of employee evaluation, it is important to avoid making assumptions about what motivates your employees. Instead, strive to understand the differences in motivation for each team member rather than simply deciding whether they are or are not motivated.

Focus on creating a dialogue with team members to discover the keys to what motivates them. Meet with each employee on your team individually and ask them what they value in their job and why they want to stay at your practice. The answers will be enlightening. Note that you are likely to get different answers to these 2 questions:

- “What motivates you in this job?”
- “What do you value most about your job here?”

An answer to the first question might be a statement about compensation or a desired schedule. The answer to the second question may be a comment on enjoying helping horses and people.

Both are valid questions that provide insight into the person’s motivation, but the second question likely speaks to what really motivates them to stay at your practice. Be sure to ask multiple open-ended questions to gain a clear understanding. One of the best follow-up questions is “tell me more about that.”
3. **Intrinsic vs. Extrinsic Rewards**

Employees have differences in how much they are motivated by intrinsic and extrinsic rewards. Extrinsic rewards include wages, benefits, bonuses, and job security. Intrinsic rewards include receiving appreciation, the ability to do a good job, and positive relationships at work.

When deciding what action steps to take to improve motivation, always consider what you are trying to motivate. Do you want to motivate retention, accountability, a higher level of job performance, greater job satisfaction, and more commitment to the business, or something else? Most practice leaders want to motivate enhanced job productivity and employee engagement, but the strategies they use only motivate retention.

4. **Focus on Enhancing Employee Engagement**

What leadership teams usually want is a higher level of employee engagement more so than more motivated employees. As you will see in the notes that follow, improving engagement leads to improved job performance.

5. **Defining Employee Engagement**

In their book *Human Sigma*, two principals of Gallup, Joe Fleming and Jim Asplund, define employee engagement as the “ability to capture heads, hearts and souls of your employees to instill an intrinsic desire and passion for excellence.” They say that “engaged” employees are emotionally and psychologically committed to the firm. Blessing White, a global consulting firm has a model of employee engagement that focuses on an individual’s contribution to company success and personal satisfaction in their job role. Wikipedia provides this straightforward definition: "Employee engagement, also called work engagement, is a concept that is generally viewed as managing discretionary effort, that is, when employees have choices, they will act in a way that furthers their organization’s interests. An engaged employee is a person who is fully involved in, and enthusiastic about, his or her work."

These three definitions reveal that employee engagement involves both job satisfaction and job contribution. The two are often linked because employees that derive rewards and satisfaction from their jobs tend to have a higher job performance.

6. **Assess Your Employees’ Level of Engagement**

With the above definitions of employee engagement in mind, consider how “engaged” you think your employees are. Undoubtedly, you will conclude that your team members have variable degrees of engagement. For the sake of simplicity, I recommend you think about whether your employees are fully engaged, partially engaged, or disengaged. This should be a relatively easy process if you consider fully engaged employees to be your shining stars and high achievers, disengaged employees to be your “bad apples” with poor job performance and negative attitudes, and partially engaged employees to be everyone else on your team. The purpose of this thought process is to get you thinking about how your employees rate in terms of their level of engagement. The next step is to thoughtfully evaluate each staff member’s job performance and job satisfaction. Create a dialogue with team members and listen carefully to whether they are really happy with their job roles. You may have employees that are productive and accountable but they may not be satisfied with their job.

7. **Take Steps to Improve Employee Engagement**

Once you assess each employee’s level of engagement, you can begin to formulate a plan to improve their engagement if necessary. Do not forget to consider your own level of engagement if you are a manager or an owner. The following list of communications and action steps have been proven to improve employee engagement:

- Create a clear vision and make sure employees know hospital goals. Establish clear purpose and meaning of job roles.
- Build trust with transparent communication and consistent adherence to hospital policies.
- Show regular appreciation to employees.
- Create opportunities for growth and learning.
- Provide consistent feedback to employees on job performance.
- Embrace autonomy. Make sure employees have some control in their jobs.

When leaders excel in these areas, they can increase employees’ job satisfaction and job performance.

8. **Communicate Vision and Core Values**

In his national bestselling book, *The 7 Habits of Highly Effective People*, Stephen Covey presented habit #2, which is to “Begin with the End in Mind.” He encourages people to “begin each day, task, or project with a clear vision of your desired direction” in order to “make things happen.” This concept is invaluable for leaders who want to improve team performance and have a positive culture. Leaders need to first visualize what they want their perfect team and culture to look like before they can successfully inspire their employees to help make the vision a reality.

The next step is to make sure the entire healthcare team knows the vision of the business. Employees cannot be expected to participate in a common effort if they do not know the goals of the practice. The team may keep rowing the boat, but they won’t arrive at the desired destination if it isn’t established by the leadership team. When team members know the vision and goals of the practice, they are more focused and understand their role in the success of the business.
9. Relate Job Duties to the Practice’s Core Values
Core values represent how veterinary teams will conduct business, and as such, they serve as a foundation for talking to staff about accountability. The core values determine the direction the team will take to reach their destination. Remind employees that all their actions need to be consistent with your core values. Be sure to reference core values in everyday communications and during team meetings. For example, when discussing tardiness, reference that “respect” is a core value of the practice and when employees are tardy, they demonstrate a lack of respect for their coworkers. Likewise, tardiness negatively affects “exceptional client service,” which is both a goal and a core value of the business. Employees are much more receptive to dialogue that is focused on core values. A discussion of inconsistent job performance no longer sounds like nagging but instead is focused on the importance of adherence to the core values and attainment of the practice goals.

10. Leadership Communications That Build Trust
There are a number of characteristics of leaders that help to build trust with employees and lead to a more productive team. One already discussed is that of clarity: being sure to communicate to the team the vision and core values of the practice. Another way leaders build trust and highly productive teams is with consistency. Employees desire transparency and a fair workplace. If the rules constantly change or favoritism exists, trust breaks down. Trusted leaders commit to consistency by following through with action on all promises or assurances and by modeling the behavior they want from the rest of the team. Here are examples of consistent behaviors that build trust:

- Always showing up on time for work.
- Treating all clients and staff the same with respect to discounts or favors.
- Adhering to deadlines as promised.
- Coming to work with a positive demeanor every day.
- Ensuring that hospital policies are adhered to by everyone on the team.

Caring leaders also build trust by having authentic connections with their team. They understand the goal is not to be everyone’s best friend or to win favor by bringing donuts to work. Instead, the goal is to create a positive, rewarding work environment. One of the ways leaders demonstrate caring is by offering regular praise and appreciation. Budgetary constraints are not a problem for caring leaders because personal thank-you cards and in-house mentoring or training cost next to nothing.

11. Focus on Employee Development
One of the best ways to motivate employees and enhance job performance is to focus on employee development. Wikipedia defines employee development as “the strategic investment, by an organization, in the training of its members.” The University of Minnesota’s Office of Human Resources states “Employee development is a joint, ongoing effort on the part of an employee and the organization for which he or she works to upgrade the employee’s knowledge, skills, and abilities.” I define employee development as efforts to assist in the professional growth and learning for team members. All these definitions are similar and focus on key aspects of employee development: training and learning for the employee and the commitment by the organization to these goals.

Employee development is not the same as an employee review process. Employee reviews assess current and past job performance. Discussion of developmental plans may or may not be part of this process. Managers use employee reviews to talk to employees about their strengths and weaknesses, outline what areas of job performance may need improvement, and may or may not give raises during this time. Although there is nothing wrong with this protocol, management teams often miss the opportunity to put an effective plan in place to assist employees with training and professional development. As a result, employee motivation and job satisfaction may suffer, which can lead to reduced employee retention. Additionally, the practice misses out on opportunities to improve employee competency and productivity.

Developmental plans should be tailored to the individual employee. Not all employees have the same interests, skills, and proficiency. For example, one technician might be interested in nutrition and patient care, whereas another may be more interested in behavior and developing their laboratory skills. Employee development forms should be used to keep a written record of plans for each employee. This form should outline the employee’s current strengths and weaknesses of job performance, current skill set and proficiencies, the employee’s interests and desired skills, training that is necessary to achieve new skills or proficiency levels, and quarterly or monthly goals. The forms should specify a timetable and deadlines for training and achievement of goals.

12. Enhance Efficiency and Productivity with Feedback
Giving your staff regular, timely feedback improves efficiency by reinforcing the job performance you want and discouraging behaviors you do not want. Feedback helps you work better with your team because employees appreciate knowing how they are doing and how they can improve.

Don’t forget to solicit feedback from staff as well, which further assists in efforts to improve hospital operations. Take the following steps to establish effective feedback protocols.
13. Communicate Clearly
Sometimes inefficiency or lack of accountability exists because managers are unclear when communicating with staff about their job performance or when delegating job tasks.

Communicate and clarify expectations to employees in a direct, straightforward manner. Be sure to assess for understanding from employees. Ask them if they have any questions about their assigned job tasks. Do not forget to give employees deadlines when delegating job tasks. Rather than asking an employee “Can you please file these records and enter these invoices?” instead say “I need these records filed and the invoices entered by the end of your shift. Can you complete this job task by 5 pm?”

14. Know When and How to Deliver Feedback
Once job tasks are delegated, employees need constructive feedback on their job performance. One of the most important aspects of giving feedback is to be specific and timely. Specific information about how job duties are performed is more meaningful than comments such as “Thanks for doing a good job” or “We need for you to do a better job.” Specific feedback tells a team member what behavior you want them to continue and/or what behavior is unacceptable. Although at times it may seem nit-picky, not everyone has the same definition of what is an “exceptional, good or poor” job performance, what is “on-time,” or what is “clean.” Be aware of appropriate times and places to give feedback. Follow the old adage, “praise in public and criticize in private.” If you need to discuss inconsistent job performance or failure to complete job tasks, then set up a private meeting with employees. Try to be sensitive to the timing of feedback if employees are going through a difficult time period. This is not to say that managers should avoid giving feedback but rather that they should convey empathy if employees are struggling with personal issues and be prepared to offer support such as employee assistance programs.

15. Focus on the Behavior Not the Person
When giving feedback, always focus on the behavior of the team member not on intangibles, such as their attitude or intention. We cannot measure, quantify, or see an employee’s attitude or intention. But we can witness behavior and actions. Rather than telling an employee they need to have a better attitude or that they need to be more efficient checking in clients, tell them specifically what words or actions demonstrate their poor attitude or poor job performance.

When you focus feedback on specific behavior and actions, employees will know what they need to do differently as well as what they need to continue doing well.

16. Coaching Your Team to Problem-Solve
If you want to empower your team to a higher level of job performance, begin by assessing their problem-solving capabilities. Do all your employees continually come to you with complaints, conflicts to be resolved, and issues to be addressed by management? Or is it just a few team members that always come to you with problems? Determine what kind of issues or problems employees complain about or ask for assistance in resolving. Your list might include items like the following:

- The client service representatives (CSRs) complain that the doctors and technicians always get mad at them about how they schedule surgeries or appointments.
- Several employees come to you saying they cannot work their shifts next month, or you always have to scramble to figure out who to call in when someone is sick.
- Your technician tells you that the infusion pump is not working properly.
- Employees or associate doctors grumble that there is not enough space for inventory items or that the treatment area/pharmacy is disorganized.
- Your CSR reports Mrs. Taylor is angry about her bill and wants you to call her.
- One technician reports another technician “has made rude remarks to me.”
- The practice manager reports she thinks you could get better health insurance rates.

After you compile your list, consider whether team members could have come up with solutions to address the issue or problem if they had the appropriate training and were empowered to take action. Making this list will also help you ascertain whether your employees are really empowered. Often, veterinarians and managers feel they have an empowered staff when in reality this is not the case.

Additionally, think about your practice culture. Is morale low or high? Do your employees always take initiative to get the job done or do they constantly have to be told what to do? Do your employees work as a team or do some staff members have an attitude of “I just work here”? If you are experiencing problems with employee motivation, lack of employee accountability, and inconsistent job performance, this is evidence that your staff may not be empowered to solve problems and take action.

17. Conduct an Employee Assessment and Identify Gaps in Training
It is important to understand that not all employees want to be empowered to problem-solve. Some employees are more comfortable with managers who delegate job tasks but do not require independent thinking or problem-solving. These employees may still be valuable team members but should not be in key positions in the practice.
Assess the current skill level and existing level of autonomy for each employee in the practice. Solicit employee feedback regarding their desire and willingness to participate in career development and contribute more to the practice. This step involves active listening on the part of management to evaluate the level of job satisfaction and perceived autonomy of each employee.

Next, identify gaps in training so that instructional programs can be initiated for employees that lack skills and expertise needed to be more empowered. Client relations personnel may need further client service or communication skills training in order to be empowered in their problem-solving efforts for clients. Technicians may need training in how to be more effective with client education. Office managers may need advanced training in management.

18. Establish Boundaries for Employees
To effectively create a team of problem-solvers, you must establish boundaries so team members understand appropriate limits and expectations. Remember that empowered employees have the autonomy to take action and problem-solve when they are at work. For example, an empowered staff member understands that exceptional client service is a core value for the practice and will act to exceed client expectations and resolve any client dissatisfaction. But, employees must know the limits and boundaries regarding what action should be taken. Clearly, management does not want CSRs to credit any amount of money on an invoice just to satisfy an unhappy client. Instead, employees should be given boundaries to know what dollar amount would be acceptable to credit in the case of a disputed bill and should be trained in other ways to resolve client dissatisfaction.

Empowered employees are held accountable for their decisions. Boundaries established for employees need to be consistent with the practice’s mission, core values, and goals. This ensures that employees make decisions based on patient advocacy, excellent client service, and sound business principles regarding profitability.

19. Provide Ongoing Coaching
Constructive feedback regarding their decisions and problem-solving capabilities helps employees excel in their jobs. If practice leaders do not feel an employee made the best decision, they should discuss the employee’s decision-making process and make suggestions for future actions. With mentoring and supportive feedback, employees learn from their mistakes.

Managers and veterinarians also need to coach team members to come to them with possible solutions, not just problems. In time, employees will learn to present one or more possible solutions when they report conflicts or problems to management. With proper coaching, many issues that previously had to be resolved by managers will be taken care of by the staff.

Promoting teamwork also helps facilitate Ongoing efforts to coach the staff to problem-solve. Teams are results-oriented rather than just task-oriented, which leads to greater organizational effectiveness. Empowered teams also generate new ideas and use conflict to create a thoughtful discussion, resulting in more effective decision-making.

20. Employee Conflict
Conflict between coworkers in veterinary practices is not uncommon, and some level of conflict among team members is inevitable. When conflicts are minor or resolved relatively quickly, the practice culture does not suffer. However, if a conflict is unresolved, the workplace can become a negative, unhappy environment where no one looks forward to coming to work.

There are two basic types of conflict, and it is important to ascertain the difference. Emotional conflict occurs as a result of anger, resentment, personality clashes, ego, and stress. Emotional conflict tends to involve heated discussions or arguments that are personal in nature. Cognitive conflict, on the other hand, occurs when someone argues the merits of their ideas or plans.

Typically, cognitive conflict stimulates creativity and discussion. With cognitive conflict, the parties involved do not make personal attacks on the other party and may have no trouble working together. You may be able to identify which type of conflict exists by assessing whether the parties are defending their position or whether they are defending themselves. Emotions tend to run high with emotional conflict, and the parties involved often do not like each other very much.

Sometimes, emotional conflict is easy to identify because the individuals fighting may have a history of not getting along. With emotional conflict, coworkers may be experiencing personality differences and/or hurt feelings. With cognitive conflict, coworkers may have a difference of opinion but are able to discuss how to resolve their differences and move forward.

21. Steps to Resolve Conflict
Conflict is not necessarily bad. In fact, some level of conflict is good because it helps to stimulate dialogue on important issues, brainstorming of solutions, and positive change. It is only when conflict escalates or is left unresolved that it becomes a problem both for employees and the success of the practice. Take the following steps to handle conflict when it occurs.

22. Anchor the Team to the Practice Vision and Core Values
One of the best ways to enhance communication and teamwork is for the leadership team to keep all employees anchored to the practice’s mission or vi-
sion and core values. If everyone is focused on achieving the hospital goals and the same value system, then it becomes easier to stamp out behaviors that are nonproductive and damaging to morale. Remember, teams exist to achieve a common goal and share joint accountability. Practices that foster teamwork and remain focused on doing what is right for patients and clients are less likely to have conflict between coworkers. When a conflict does occur, the vision and core values of the business serve as a roadmap to guide actions taken to resolve the conflict.

23. Implement Effective Communication Protocols

If the primary forms of communication include leaving notes for each other and employees feel like they are not kept informed, then you likely need better communication systems. Use email and posted memos only for information that is not sensitive and requires no discussion. Use staff meetings and face-to-face meetings for communication on topics that may generate questions. This helps avoid conflict that may arise because coworkers did not understand or have the opportunity to state their opinion regarding policies and procedures. Encourage team members to speak up at staff meetings so any concerns that may lead to conflict can be discussed.

24. Encourage Open Communication between Coworkers

Ideally, conflict is best resolved between employees when possible. This is particularly true if emotional conflict exists. Encourage team members to see if they can work out their differences without having to involve a third party, such as a supervisor or manager. Ask them to find a time for both parties to talk when each person is calm. Many times, sitting down to talk allows employees an opportunity to better appreciate the feelings of the other person. The goal is to try to turn any emotional conflict into cognitive conflict. Often, coworkers just need to feel like the other person understands their position. Once coworkers feel like they have been heard, they may be able to come up with possible solutions to resolve the current conflict and avoid future conflict.

25. Meeting with Managers

When employees try talking to their coworker and cannot resolve conflict or feel that someone is unapproachable, it may become necessary to seek assistance from a supervisor or the practice manager. Managers need to be prepared to mediate and offer possible solutions to resolve conflict. Many practices find it helpful to refer coworkers to an employee assistance program for assistance with conflict resolution, stress management, or anger management.

26. Focus on Creating Win/Win

In Stephen R. Covey’s book, The 7 Habits of Highly Effective People, he says “the habit of effective interpersonal leadership is Think Win/Win.” He points out that win/win is a paradigm of human interaction, that it is a philosophy and frame of mind. The application of this concept for our topic here is that employees should strive to find win/win relationships with coworkers. Rather than complaining, employees should always try to find a way to help each other, build trust, and problem solve together for the benefit of the practice. For example, if a CSR finds that one of the technicians is unhappy about having to see “crazy Mrs. Jones,” then the CSR could offer to assist with the interaction and schedule Mrs. Jones with a different technician next time. Likewise, technicians can help out CSRs by being willing to assist them during hectic times. Employees are more likely to help a coworker if that coworker has helped them at some point.

27. Be Willing to Terminate Poor Performing Employees

To create a positive culture characterized by adherence to core values and excellence, management must be willing to fire employees that don't measure up. Otherwise, accountability efforts falter and trust breaks down because employees realize there is no consequence for failing to be accountable. Moreover, team performance suffers if poor performing team members or, worse yet, toxic employees aren't terminated.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.
Introduction to Equine Chiropractic Evaluation and Treatment Techniques

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Equine chiropractic techniques provide unique methods of assessment and treatment that have moderate evidence of effectiveness in reducing back pain and muscle hypertonicity, improving trunk flexibility, and restoring symmetrical thoracolumbar movement patterns in horses. Manual therapies can provide important adjunctive diagnostic and treatment options in improving performance in athletic horses. Author's address: College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: Kevin.Haussler@ColoState.edu. © 2018 AAEP.

1. Introduction

Manual therapy involves the application of the hands directly to the body, with the goal of diagnosis and treating soft tissue injuries or articular dysfunction. Muscle soreness, joint stiffness, and vague, poorly localized lameness or reduced performance are all common clinical indications for applying manual therapies. Chiropractic, osteopathy, massage therapy, therapeutic touch, and certain physical therapy techniques are all considered to be types of manual therapy that have been first developed in human medicine and then later applied to horses. Manual therapies can be classified or grouped based on the type of force applied or tissue of interest. Low-force or very light manual techniques might include superficial touch or massage, and more forceful techniques might include limb protraction or retraction stretches or chiropractic treatment. Therapeutic touch focuses on light manual stimulation of the skin and superficial fascia by using a variety of small circles or stroking techniques. Massage techniques typically focus on muscle soreness and myofascial restrictions. Joint mobilization and manipulation are two types of induced articular movements used in musculoskeletal rehabilitation to restore joint function. Mobilization is characterized as repetitive joint movements induced within the normal physiological range of joint motion. Joint mobilization techniques are commonly used by chiropractors, osteopaths, and physical therapists to assess and treat restrictions in the quality and quantity of joint motion.

The word chiropractic is derived from the Greek words cheir, meaning “hand,” and praktike, meaning “business” or “to practice.” The practice of chiropractic focuses primarily on the evaluation and treatment of articular structures as a means to influence neurologic pathways (e.g., pain inhibition, mechanoreceptor facilitation). Chiropractic uses small amplitude thrusts that are manually or mechanically applied to specific joints or anatomical regions to induce therapeutic responses through induced changes in joint structures, muscle function, and neurological reflexes. Both human and equine research have demonstrated reductions in pain and muscle hypertonicity and increased joint range of motion after chiropractic treatment. Joint mobi-
lization and manipulation induce different physiological responses, and manipulation seems to provide a larger clinical effect in both humans and horses.\textsuperscript{1,2} The focus of this review is to provide an introduction to equine chiropractic evaluation and treatment techniques.

2. Practitioner Qualifications

All manual therapies involve assessing musculoskeletal function with the goal of reducing pain, muscle hypertonicity, and stiffness. Additional neurologic effects may include improved performance and a sense of well-being. As the light-touch or low-force techniques are less technically challenging, many lay practitioners are involved in providing these services. However, the efficacy and clinical usefulness of these techniques as applied by nonveterinarians should not be dismissed. The combination of massage and chiropractic does seem to be useful in some horses, and the time and effort required to provide both of these services in a single visit is not effective from a time or cost perspective for most veterinary practitioners.

Equine practitioners have seen a recent proliferation in the use of chiropractic techniques on horses, in one form or another. Veterinarians currently do not receive any formal education in chiropractic principles or techniques in their veterinary training; therefore, many equine clinicians may not have a basic understanding of chiropractic principles or clinical applications. Conversely, human chiropractors do not have any formal training in comparative anatomy, physiology, pathology, or clinical equine experience. Veterinary medicine, for the most part, has been forced to acknowledge the use of chiropractic and other nontraditional modalities by horse owners or trainers that have sought practitioners who use these techniques and have experienced their perceived therapeutic effects.\textsuperscript{3} If veterinarians have not taken the time or effort to learn more about these nontraditional techniques, objectively evaluating the use of chiropractic, discussing the indications or contraindications for a specific treatment modality, or applying these techniques clinically is often difficult. To complicate matters, many laypersons claiming to be equine chiropractors are not professionally trained or licensed in chiropractic or veterinary medicine. These lay practitioners often have a limited knowledge of equine musculoskeletal anatomy, physiology, biomechanics, or pathology. Because of the potential misapplication, chiropractic evaluation and treatment should be provided only by licensed professionals (i.e., veterinarians or human chiropractors working under the direct supervision of a veterinarian) who have pursued additional postgraduate training in animal chiropractic principles and techniques. The primary organizations in North America currently involved in training and certifying veterinarians and chiropractors in animal chiropractic are Options for Animals based in Wellsville, Kansas, Parker College of Chiropractic in Dallas, Texas, and The Healing Oasis Wellness Center in Sturtevant, Wisconsin. An additional course on equine osteopathy is offered at the Vluggen Institute in San Marcos, Texas.

As state veterinary and chiropractic practice acts vary considerably as to allowing human chiropractors to evaluate and treat animals, it is suggested that practitioners consult their individual state practice acts to determine the process required for veterinarians and chiropractors to work together in evaluating and treating patients and providing appropriate follow-up care. It is strongly recommended that owners and referring veterinarians seek out licensed professionals (veterinarians or chiropractors) who have had specialized training and experience in chiropractic evaluation and treatment of horses. Veterinarians who have not pursued formal postgraduate training are not qualified to provide chiropractic care and risk producing more harm than potential benefit. It is a good idea to ask equine chiropractors about their professional and postgraduate training or certification, horse experience, and the types of techniques that they use (i.e., hands only versus more aggressive techniques or the use of additional instruments). Chiropractic or osteopathy requires a working knowledge and understanding of vertebral anatomy, physiology, biomechanics, pathology, and rehabilitation. Combining the knowledge and expertise of the veterinary and chiropractic professions provides practitioners with new insights and methods for diagnosing and managing horses with select vertebral or musculoskeletal disorders. A similar multidisciplinary approach has developed in human medicine to address chronic pain syndromes and spinal disorders in the last decade.

3. Clinical Indications

Chiropractors often have been asked to treat the animals of owners or trainers who have experienced the benefits of chiropractic care for their own back or neck problems. Horse owners often want the opportunity to have the same type of care for their horses, without the potential adverse effects of medications or surgery. The recent increased awareness of the prevalence and management options to address back problems, with which traditional veterinary medicine has had difficulty in dealing, has also stimulated horse owners’ interest in complementary forms of treatment.\textsuperscript{4} Any vertebral column disorder can have serious effects on a horse’s ability to perform.\textsuperscript{5} Back problems can be classified into three basic types of injuries involving the muscles, tendons and ligaments (soft tissue injuries), bones and joints (osseous injuries), or nervous system (neurological disorders). However, several concurrent injuries have been reported in 17% of horses with back pain.\textsuperscript{5} Diagnosis of the underlying vertebral pathological conditions in horses with back pain is important for the appropriate treatment and management of these disorders.
Many horses in which chiropractic may be useful often have a history of a traumatic event or an injury related to overexertion. Trauma may occur as a single event (i.e., macrotrauma), such as a trailer accident, flipping over backward, or substantial falls over jumps. Severe musculoskeletal injuries may improve gradually, but they never resolve totally or subsequently debilitating arthritis or soft tissue fibrosis may develop. Chronic, overuse injuries (i.e., microtrauma) usually are associated with poor saddle fit, improper riding techniques, inadequate shoeing, or faulty conformation. Long periods of confinement, inconsistent training programs, or cumulative stresses and strains related to prolonged, high-level athletic activities also may predispose horses to musculoskeletal injuries and reduced performance. Older horses, similar to elderly people, are susceptible to loss of vertebral column flexibility, joint degeneration, and loss of muscle strength. Aged horses also have increased healing times and increased chances of having chronic conditions or abnormal musculoskeletal compensations from prior injuries. Chiropractic techniques have helped identify and treat some of these previously undiagnosed or poorly managed problems in horses. Veterinarians trained in chiropractic techniques often use the specialized diagnostic and treatment approaches that chiropractic provides to complement their conventional veterinary practice or lameness evaluation procedures.

Prevalence of back problems in horses varies greatly (from 0.9% to 94%), depending on the specialization or type of practice surveyed: general practice (0.9%); Thoroughbred racehorse practice (2%); veterinary school referrals (5%); mixed equine practice including dressage, show jumpers, and eventing (13%); spinal research clinic (47%); or equine chiropractic clinic (94%). Clinicians often have difficulties when dealing with horses with no obvious localized pain or vague, unspecified lameness. Neck or back problems and limb injuries often are interrelated. Across several studies that assessed the presence of back problems and lameness issues within the same horses, approximately 75% (range, 35% to 85%) that had back pain had concurrent limb lameness; whereas, about 25% (range, 23% to 32%) of the horses presented for limb lameness also had signs of back pain. Therefore, equine chiropractors that focus solely on axial skeleton issues are not addressing about 75% of their patients that have concurrent limb lameness. Conversely, practitioners that focus solely on limb lameness may disregard the influence of back pain on altered gait patterns in about 25% of their patients. The best approach from a sports medicine and rehabilitation perspective is to address all sites and sources of pain as they present within individual patients. The approach of injecting the distal tarsal articulations and making the assumption that signs of back pain will resolve spontaneously is outdated and inappropriate for most horses.

Distal limb injuries can cause an alteration in carriage of the affected limb and altered gait, which subsequently can overwork or injure proximal limb musculature and the paraspinal musculature. Similarly, vertebral column injuries can produce gait abnormalities, increased concussive forces, and distal limb lameness. The diagnostic dilemma facing clinicians is to decide whether the limb or the vertebral column is the primary or initial cause of the horse’s clinical problem. Unless the primary cause of the neck or back pain is identified and treated, most horses will have recurrent back pain when returned to work after a period of rest or trial of anti-inflammatory medications.

4. Clinical Evaluation

Chiropractic provides expertise in evaluating vertebral column disorders and can provide an additional means of diagnosis and early treatment options in certain types of gait abnormalities or performance problems. Prepurchase examinations using chiropractic examination techniques also can help identify horses that have chronic underlying neck or back problems. Chiropractic addresses subclinical conditions or abnormal biomechanics, which may progress to future debilitating musculoskeletal injuries. Chiropractors are also trained in using physiotherapy modalities, strength training exercises, massage, stretching techniques, and other forms of musculoskeletal and nerve rehabilitation. Equine chiropractic is a complementary modality that can be used in veterinary medicine for the diagnosis, treatment, and potential prevention of select musculoskeletal disorders in horses. However, a few recent studies have investigated the effectiveness but not the safety or cost-effectiveness of chiropractic procedures in veterinary medicine.

Chiropractic, like any medical evaluation, begins with a thorough history, discussion of the chief complaint, and observation of the patient from a distance for conformation, posture, and signs of lameness. Chiropractic evaluation and treatment is not a substitute for a thorough lameness examination and diagnostic workup because many horses have musculoskeletal conditions that are identified readily and managed with traditional approaches. In veterinary medicine, many structural abnormalities of the vertebral column are becoming easier to diagnose with newer imaging modalities (e.g., computed tomography, scintigraphy, and ultrasonography). Currently most clinicians are not well educated or experienced in procedures required to perform a thorough functional evaluation of the equine vertebral column. Therefore, horses with conditions not diagnosed readily using traditional modalities, or with suspected concurrent neck or back problems, may require referral for chiropractic evaluation.

Horses with conditions that may be responsive to chiropractic care have a variety of nonspecific or vague problems. The focus of the chiropractic ex-
amination is placed on evaluating static and dynamic characteristics of the musculoskeletal system. Initially, the horse’s general attitude and behavior are monitored for signs of pain or discomfort. Vertebral column conformation is evaluated for proper alignment and symmetry, with special attention to the top line, shape and height of the withers, and osseous pelvic symmetry. A short-coupled horse is thought to have a higher incidence of osseous disorders, whereas a long-backed horse is more prone to soft tissue injuries. Conformation is a structural relationship of body segments, whereas postural analysis deals more with functional relationships. The horse is made to stand on a hard, level surface and is evaluated for a preferred or shifting stance, head and neck carriage, vertebral curvatures, and muscular symmetry. Chiropractic gait analysis focuses on evaluating regional vertebral mobility and pelvic motion symmetry, in addition to the typical assessment of forelimb and hindlimb lameness. Gait analysis may help to rule out distal limb disorders and to rule in vertebral dysfunction, although limb lameness has been reported in up to 85% of horses with back problems. Motion asymmetries, restricted vertebral or pelvic mobility, not tracking straight, or lack of propulsion are a few characteristics that are evaluated. Tape on the tuber coxae or vertebral column midline may help to see subtle motion asymmetries. Normal vertebral column motion consists of small cumulative amounts of segmental motion, which produce an overall smooth curve or movement of the vertebral column. Evaluation of the response to placing a saddle on the horse and being ridden is important for a complete assessment of horses with back problems. Inspection of the tack for proper use and fit are always suggested on initial examination. Saddles and restraint devices should be evaluated for proper fit, padding, and positioning on the horse.

A thorough physical examination is used to eliminate other more common causes of lameness or neurological disorders. Chiropractic evaluation focuses on evaluating and localizing segmental vertebral dysfunction, which is characterized by localized pain, muscle hypertonicity, and reduced joint motion. Palpation is used to localize and identify soft tissue and osseous structures for changes in texture, tissue mobility, or resistance to pressure. Soft tissue layers are evaluated from superficial to deep in two ways: by increasing digital pressure and by shifting attention with discrete palpatory movements. Shapes of structures, transitions between structures, and attachment sites also may be palpated. Soft tissue texture and mobility can be compared between the skin, subcutaneous tissue, thoracolumbar fascia, and muscle. Patient response to palpation is important especially in evaluating tenderness or hypersensitivity. Osseous palpation involves evaluating osseous structures for pain, morphology, asymmetries, and alignment. Many horses with dental problems or malocclusion have localized pain during palpation of the temporomandibular joints and hypertonicity of the adjacent muscles of mastication. Osseous asymmetry of the space between the ramus of the mandible and the lateral wing of the atlas (first cervical vertebra) can be identified in horses with upper cervical congenital malformations, poll trauma caused by pulling back or falling over, or in some horses that head toss. The apices of the thoracic and lumbar spinous processes are readily palpable in most horses, unless they are grossly overweight. The dorsal apices of individual spinous processes are palpated with firm manual pressure, while monitoring for a localized pain response or muscle hypertonicity, indicative of local injury or impinging spinous processes. Palpable deviations of individual spinous processes are common, but usually they are not associated with spinous process fracture or vertebral malposition (i.e., bone out of place), as is commonly thought. Overlapping or misaligned dorsal spinous processes are often caused by spinous process impingement, developmental asymmetries in the neural arch, or isolated dorsal spinous process deviation of unknown cause. During induced kyphosis, the abaxial borders of each individual thoracolumbar spinous process and the overlying supraspinous ligament are palpated for pain, thickening, or deviation from midline. The tubera sacrale are palpated for height asymmetries and evaluated for a localized pain response to manual pressure applied dorsally or during abaxial compression. The apices of the sacral spinous processes (of the second to fifth sacral vertebrae) are palpated for pain or deviation from midline.

A complete musculoskeletal examination includes assessment of active and passive ranges of joint motion for all axial and appendicular articulations. Active joint range of motion is evaluated during induced vertebral movements (carrot stretches) and gait analysis. Assessment of passive range of motion requires muscular relaxation as the articulations are moved passively throughout the individual joint ranges of motion. Abnormal segmental vertebral motion is detected when joint motion is asymmetrical or restricted bilaterally. Causes of segmental vertebral motion restrictions include capsular fibrosis, effusion, or inflammation. Regional causes of vertebral movement restrictions may include periarticular soft tissue adhesions, musculotendinous contractures, or, more commonly, protective muscle spasms. By combining the evaluation of joint range of motion and the presence or absence of pain at the extremes of joint motion, diagnostic interpretations can be implied. Normal joint motion is painless, suggesting that articular structures are intact and functional. Normal joint mobility that has a painful end range of movement suggests that a minor sprain of the associated articular tissues is present. Painless joint hypomobility suggests that a contracture or adhesion is present. Painful hypomobility suggests an acute strain.
with secondary muscle guarding. Painless hypermobility of an articulation may indicate a complete rupture, whereas painful hypermobility suggests a partial tear of the evaluated structure.

Joint mobilization is used to evaluate each vertebral segment for loss of normal range of motion (i.e., quantity) and overall resistance to induced motion (i.e., quality). Vertebral segments with altered motion palpation findings can occur with or without localized muscle hypertonicity and pain. Using palpation to evaluate the musculoskeletal system requires an understanding of how joint motion is assessed. Moving an articulation from a neutral position first involves evaluating joint motion that has minimal and uniform resistance. As the articulation is moved toward the end range of motion, a gradual increase in the resistance to movement occurs (i.e., elastic barrier). End range of motion starts when any change in resistance to passive joint movement is palpable. The elastic barrier is evaluated by bringing the articulation to tension and applying gentle, rhythmic oscillations to qualify the resistance to movement. The normal joint end feel is initially soft and resilient and gradually becomes more restrictive as the maximal joint range of motion is reached. This elastic barrier marks the end of physiological joint movement. A pathological or restrictive end range of motion is palpable earlier in passive joint movement and has an abrupt, restrictive end feel compared with normal joint end feel. The goal of palpating joint movement is to evaluate the initiation of motion resistance, the quality of joint motion and end feel, and the overall joint range of motion. Joint movement beyond its normal anatomical limits is characterized by ligamentous or articular capsule disruption and joint subluxation.

Individual vertebral segments are evaluated for altered motion palpation findings in flexion and extension, right and left lateral flexion, and right and left rotation. In a relaxed horse, the articulations of the individual second to sixth cervical vertebrae are assessed for the presence or loss of the normal elastic barrier during combined lateral flexion and rotation. The articulation between the fourth and fifth cervical vertebrae seems to be commonly affected in most performance horses, presumably because of locally altered biomechanical influences. The individual spinous processes of the third to twelfth thoracic vertebrae are deviated manually from the midline, while monitoring for signs of reduced vertebral motion, localized pain, and induced muscle hypertonicity. Horses with poorly fitting saddles (i.e., tree too narrow) resist motion palpation of the affected vertebrae. The remaining thoracolumbar region is assessed in lateral bending and flexion and extension for similar signs of joint dysfunction. While the clinician stands next to the horse, segmental vertebral motion in lateral bending is assessed with one hand lying over the intervertebral articulation to be evaluated. The other hand is placed at the tail head and is used to induce rhythmic oscillations to the caudal vertebral column. Normal lateral bending is maximal at the mid-thoracic vertebral region and gradually diminishes toward the lumbosacral junction. Conversely, flexion and extension are minimal in the thoracic region and gradually increase to the lumbosacral junction, the site of maximal flexion and extension. Segmental vertebral motion in flexion and extension requires the clinician to be on an elevated surface to induce ventrally directed rhythmic oscillations to the intervertebral articulations of the thirteenth to sixteenth thoracic vertebrae. The sacroiliac joints are evaluated for motion restriction or pain during induced joint motion, with an applied force directed ventrally over the tuber coxae, or during abaxial compression of the tubera sacrae. The caudal vertebrae are assessed by manipulation of individual vertebrae or by applying axial traction. The range of motion of the individual forelimb and hindlimb articulations also are evaluated in flexion and extension, internal and external rotation, abduction and adduction, and circumduction for signs of reduced joint motion, localized pain, and induced muscle hypertonicity. Palpation of the entire musculoskeletal system, including joint motion assessment of the axial and appendicular skeleton, can be accomplished within 15 to 20 minutes.

A neurological examination is indicated to evaluate horses with back problems to rule out traumatic, infectious, and toxic causes. Postural reactions also help to assess the proprioceptive status, which may be compromised in horses with certain vertebral column disorders. Transrectal palpation is a commonly forgotten diagnostic test in horses with back problems. Osseous palpation rectally is useful for evaluating fractures, pelvic canal symmetry, and lumbosacral or sacroiliac joint degenerative joint disease. Externally induced pelvic motion during rectal palpation helps to assess lumbosacral joint motion internally. Palpation of the iliopsoas muscles for pain, swelling, or asymmetry is also important in evaluating horses with back pain. If sedation is required, then the clinical significance or influence of sedation on reducing the horse’s response to nociceptive stimuli or applied mechanical pressure needs to be carefully considered.

An orthopedic examination commonly is indicated to rule out or identify concurrent limb problems. Hematological evaluation, diagnostic analgesia, muscle biopsies, or cerebral spinal fluid analysis may be required in certain horses before chiropractic assessment and treatment. Imaging modalities that may contribute to a definitive diagnosis in horses with neck or back problems include radiography, myelography, ultrasonography, scintigraphy, computed tomography, and thermography. A thorough diagnostic workup and a definitive diagnosis, when available, are important for tailoring the appropriate chiropractic treatment and rehabilitation program. Horses with developmental osseous abnormalities, cervical vertebral fractures, thoraco-
lumbar impinged dorsal spinous processes, equine protozoal myelitis, and sacroiliac joint luxation have been referred for chiropractic consultation. It was critical that these horses were properly diagnosed and that inappropriate chiropractic treatment was not applied, especially as the sole or primary therapeutic modality.

5. Indications for Chiropractic Care

Chiropractic provides additional diagnostic and therapeutic approaches that are not currently available in veterinary medicine. The principal indications for equine chiropractic evaluation are acute or chronic neck or back pain, localized or regional joint stiffness, poor performance, and an altered gait that is not associated with overt lameness. Musculoskeletal conditions that are chronic or recurring, are not diagnosed readily, or do not respond to conventional veterinary care also may be indications for chiropractic consultation. A thorough diagnostic workup is required to identify soft tissue and osseous pathological conditions, neurological disorders, or other lameness conditions that may not be responsive to chiropractic care. Horses with a localized limb lameness or diagnosed neurological disease are better treated with conventional veterinary medicine. However, if a residual lameness continues or a secondary vertebral column disorder (e.g., stiffness or asymmetry) is identified, then concurrent chiropractic care is indicated. Horses that have concurrent hock pain (e.g., osteoarthritis) and a stiff, painful thoracolumbar or lumbosacral vertebral region are best managed by addressing all areas of musculoskeletal dysfunction. A multidisciplinary approach entails concurrent medical treatment of the hock osteoarthritis and chiropractic evaluation and treatment of the back problem. Most horses respond favorably to concurrent management, and owners appreciate a complete and thorough medical evaluation and treatment. Similarly, horses with chronic forelimb lameness often have compensatory pain and stiffness in the withers region that is readily addressed with chiropractic or physical therapy techniques.

The primary clinical signs that equine chiropractors assess are areas of localized musculoskeletal pain, muscle hypertonicity, and restricted joint motion. This triad of clinical signs can be found in a variety of distal limb disorders, but it is most evident in neck or back problems. In general, localized pain, reduced vertebral segment motion, and local muscle spasms in the vertebral column are indications of a primary spinal disorder. In contrast, regional or diffuse pain, generalized stiffness, and widespread muscle hypertonicity are indications of a chronic or secondary spinal disorder, and further diagnostics should be done to identify the primary cause of lameness or poor performance. Chiropractic care may provide symptomatic relief in horses with early vertebral osteoarthritis if related to joint hypomobility and subsequent immobilization.

6. Mechanism of Action

Multiple theories have been proposed and tested over the years to explain the causes of vertebral segment dysfunction in people and its effects on the neuromusculoskeletal system.19,20 The chiropractically defined vertebral subluxation complex is a theoretical model that incorporates the complex mechanical and biochemical interactions of injured nervous, muscular, articular, ligamentous, vascular, and connective tissues.15 The theory of a “bone out of place” is outdated and not supported by current human or animal spinal research. Unfortunately, there continue to be some practitioners that refer to “the poll is out” or the horse “has a rib out.” These descriptors do not provide any useful insights into clinical signs of local pain, stiffness or muscle hypertonicity that are typically addressed with chiropractic care.

The goal of chiropractic treatment is to reduce pain and muscle hypertonicity, restore joint motion, and stimulate neurological reflexes. The exact mechanisms by which chiropractic techniques produce therapeutic effects are not certain. Chiropractic treatment may reduce musculoskeletal pain by stimulating nociceptive reflexes and release of neurotransmitters (i.e., endorphins and enkephalins).19,21,22 Concurrent muscle spasms restrict joint motion and may contribute to the further development of joint stiffness. In humans, palpatory changes in osseous symmetry after manipulation often are associated with soft tissue alterations and not actual reduction of an articular misalignment.17 Chiropractic care
can improve restricted joint motion and may reduce the associated harmful effects of joint immobilization.\textsuperscript{19,20} In response to chronic pain or stiffness, new movement patterns are learned by the nervous system and adopted in an attempt to reduce pain or discomfort. Long after the initial injury has healed, adaptive or secondary movement patterns may continue to persist that predispose additional joints or muscles to injury.\textsuperscript{17} Chiropractic treatment is thought to affect mechanoreceptors (i.e., Golgi tendon organ and muscle spindles) to induce reflex inhibition of pain and reflex muscle relaxation and to correct abnormal movement patterns.\textsuperscript{15,22} Additional modalities used to address altered movement patterns in people and horses include stretching or relaxing hypertonic muscles, strengthening weak muscles, and re-education of movement patterns.\textsuperscript{17}

Successful chiropractic treatment requires specific techniques and psychomotor skills.\textsuperscript{20} A thorough knowledge of vertebral anatomy and joint biomechanics is required for proper chiropractic evaluation and treatment. Joint manipulation often induces a palpable release or movement of the restricted articulations. An audible cracking or popping also may be heard during chiropractic treatment as the applied force overcomes the elastic barrier of joint resistance.\textsuperscript{23,24} The rapid articular separation produces a cavitation of the synovial fluid.\textsuperscript{25} Radiographic studies of synovial articulations after manipulation in people have shown a radiolucent cavity within the joint space (i.e., vacuum phenomenon) that contains 80\% carbon dioxide and lasts for 15 to 20 minutes. A second attempt to recavitate the joint will be unsuccessful and potentially painful until the intra-articular gas has been reabsorbed (i.e., refractory period).

7. Contraindications

Chiropractic is not a cure-all for all back problems and is not suggested for treatment of horses with fractures, infections, neoplasia, metabolic disorders, or nonmechanically related joint disorders. Serious diseases requiring immediate medical or surgical care need to be treated by conventional veterinary medicine before any chiropractic treatment is initiated. However, chiropractic care may contribute to the rehabilitation of most horses postoperatively or those with medical conditions by helping to restore normal musculoskeletal function. Chiropractic care usually is contraindicated in horses with acute stages of soft tissue injury. However, as the soft tissue injury heals, chiropractic has the potential to help restore normal joint motion, thus limiting the risk for future reinjury.\textsuperscript{17} Acute episodes of osteoarthritis, impinged dorsal spinous processes, and severe articular changes, such as joint subluxation or luxation, are often contraindications for chiropractic. Unfortunately, many human and veterinary chiropractors continue to use the term “subluxation” as a critical component of chiropractic diagnosis and treatment, which has distinctly different connotations and implications compared with the traditional or medical definition of subluxation (i.e., incomplete or partial dislocation of a joint that is clearly demonstrated on radiographs). All horses with neurological diseases should be evaluated fully to assess the potential risks or benefits of chiropractic treatment. Cervical myelopathy occurs because of structural and functional disorders in the cervical vertebrae. Static compression caused by vertebral canal malformations and dynamic lesions caused by vertebral segment hypermobility are contraindications for cervical manipulation. However, adjacent hypomobile vertebrae may require chiropractic treatment to help restore joint motion and reduce biomechanical stresses in the affected vertebrae. Chiropractic care cannot reverse severe degenerative processes or overt pathological conditions.

8. Chiropractic Techniques

Chiropractic care provides important therapeutic approaches that are not currently available in veterinary medicine. Most of the current knowledge about equine chiropractic has been borrowed from human chiropractic techniques, theories, and research and adapted to animals. Therapeutic trials of chiropractic manipulations often are used because knowledge is limited about the effects of chiropractic care on animals. Chiropractic addresses mechanically related disorders of the musculoskeletal and nervous systems and provides a conservative means of treatment and prevention for horses with back problems. Chiropractic treatment uses an applied, controlled force to a specific anatomical region or osseous structure to produce a desired therapeutic response. Chiropractic manipulations are typically applied to areas of vertebral segment dysfunction (i.e., pain, stiffness, and muscle hypertonicity) but can also be applied to the appendicular skeleton and articulations. The condition of the horse is monitored closely as the neuromusculoskeletal system responds to the applied treatment. The applied treatment influences joint, muscle, and nerve function via mechanical and biological mechanisms.\textsuperscript{19} The therapeutic dosage of the applied chiropractic manipulation is modified by the number of vertebrae treated, the amount of force applied, and the frequency of treatment. The goal of chiropractic care is to restore normal joint motion, stimulate neurological reflexes, and reduce pain and muscle hypertonicity. Comparisons of sensitivity to palpation, muscle tone, and joint motion are made before and after treatment to evaluate the response to chiropractic treatment.

Clinicians and clients often ask the following: How can a 500-kg horse be treated with chiropractic techniques? The answer is one vertebral segment at a time. Recent equine chiropractic research has demonstrated that forces applied to instrumented vertebral segments do induce substantial vertebral motion, usually beyond the nor-
mental range of segmental motion that occurs during locomotion. Segmental vertebral motion characteristics induced during chiropractic treatment in horses are similar to those reported in people. In a relaxed horse, the mass (i.e., vertebral segment) that is affected by the rapidly applied force is proportionately smaller than the mass of the clinician applying the treatment. However, if the horse does not relax the paraspinal musculature, then the mass that is affected increases dramatically from the mass of a few vertebral segments to the mass of the entire vertebral region, or potentially the entire horse. Effective joint mobilization or manipulation cannot be applied to a nervous, tense horse without risk of injury to the horse or the clinician. Chiropractic treatments in horses usually are done without any sedation or other medications but may occasionally be done with sedation or under general anesthesia in extreme cases or coupled with intra-articular injections as indicated. Treatment of sedated horses requires modification of the applied thrust and awareness of the reduction or loss of normal protective neuromuscular reflexes. Typical indications for manipulation in humans under anesthesia include chronic myositis or fibrosis or acute musculoskeletal pain, where reflex muscle spasms prevent a thorough assessment or impede manipulative treatment. Untrained professionals who do not have thorough understanding of joint physiology, vertebral anatomy, or chiropractic principles resort to overly aggressive and forceful means of applying an external force (e.g., rubber mallets or 3 to 4 “strong men”). Small, rapidly applied manual forces are easier to control and have a lower risk of soft tissue or bone injury than more often forceful types of manipulation. A good rule of thumb would be that if a procedure does not look like something that a practitioner would be willing to have done to oneself, then maybe the procedure should not be done to a horse.

Horses are usually held by a trained handler on a loose lead during chiropractic treatment. The cervical vertebrae, sacrum, and extremities are evaluated and manipulated as needed from ground level. However, the thoracolumbar vertebrae and pelvis often require an elevated surface on which to stand for effective manipulation and proper positioning of the clinician. Equine chiropractic is physically demanding and requires significant mental concentration. The clinician and the horse must be relaxed and focused on each other. Environmental distractions are counterproductive to effective chiropractic care. Muscle relaxation allows evaluation of the elastic barrier of the joint. Motion palpation is used to evaluate joint motion restrictions so that the manipulative thrust can be applied correctly. Stabilization of adjacent joints or vertebral segments is required for proper joint manipulation. Typically, an immediate reduction in pain and an increase in segmental vertebral motion are noted. Most horses also have increased muscle relaxation, but other therapies (i.e., acupuncture or stretching) often are used with chiropractic treatment to completely resolve any remaining muscle hypertonicity. In general, conditions with an acute onset respond rapidly, whereas chronic conditions usually require longer treatment or rehabilitation. Horses with acute pain or vertebral column trauma may require initial anti-inflammatory medication, physiotherapy modalities (e.g., ice), or rest before chiropractic treatment. If stiffness, local muscle hypertonicity, or pain remains, then two or three chiropractic treatments may be indicated. Horses with chronic neck or back stiffness may require monthly evaluation and treatment for several months’ duration. Owners often request chiropractic evaluation at the beginning of the performance season, a few days after athletic competition, or as a general assessment of the overall musculoskeletal system. Similarly, horses may benefit from chiropractic treatment several days before an event. Because of ethical considerations or possible masking of musculoskeletal dysfunction, it is not recommended that chiropractic treatment be performed immediately before or during any competition. Posttreatment recommendations for actively training horses usually include stall rest or pasture turnout for one day, which provides an opportunity for the musculoskeletal system to respond to the applied treatment without immediate re-exposure to potential inciting factors of the vertebral segment dysfunction. The horse is asked to return to normal work the next day, unless other musculoskeletal injuries are present, for which appropriate supportive care is recommended. If stiffness or soreness is noted after chiropractic treatment, then an additional day of rest is suggested.

9. Complications or Adverse Effects
Potential adverse effects from properly applied chiropractic treatments include a transient stiffness or worsening of the condition after treatment (i.e., aggravated complaint, worsening of pre-existing state, regional soreness, or lameness). Adverse reactions from properly applied vertebral manipulation are typically uncommon, but they may occur immediately after treatment or insidiously within 6 to 12 hours. The undesired effects usually last less than 1 to 2 days and resolve without concurrent medical intervention. If increased or acute musculoskeletal dysfunction or lameness is noted after chiropractic treatment, then a thorough re-examination and appropriate medical treatment or physiotherapy should be pursued. If the condition does not improve with conservative care, a referral for more extensive diagnostic or therapeutic modalities is recommended. Potential harmful side effects from improperly applied manipulation from untrained individuals may include permanent articular damage or loss of function (i.e., torn ligaments, injured muscles, luxated joints, fractures, or possible paralysis if a severe underlying pathological condition is present).
10. Adjunct Recommendations and Prognosis

Chiropractic care often is supplemented with massage, physiotherapy modalities, and stretching or strengthening exercises to help soft tissue rehabilitation and to help restore normal vertebral joint motion. These concurrent therapies also help to encourage owner participation in the healing process and provide close monitoring of the patient’s progress. Other recommendations may include changes in training schedules or activities, corrective shoeing, or tack changes. Horses with ill-fitting saddles often have localized pain and muscle hypertonicity in the caudal withers region. Saddle refitting, coupled with chiropractic treatment of the painful withers region, leads to rapid recovery and management of a common problem for many horse owners. A horse with a 6-month history of consistently resenting saddle placement and bucking the owner off was treated chiropractically and in the next week won 11 ribbons at the local country fair. Many horses with repetitive-use disorders may benefit from cross-training activities. Clinicians also have reported synergistic therapeutic effects with the combined use of chiropractic, acupuncture, and other holistic modalities in equine patients. In general, horses with conditions with an acute onset respond rapidly and have a good prognosis for return to function. Horses with chronic injuries may gain only short-term improvement of restricted motion, pain, or muscle hypertonicity. This corresponds to current research on joint immobilization and spinal learning. Horses with chronic conditions usually require a series of treatments to affect a more lasting improvement. Musculoskeletal health depends on movement and use. Scientific evidence suggests that long-term rest or inactivity is contraindicated for back problems in people.

11. Equine Chiropractic Research

The focus of recent equine manual therapy research has been on assessing the clinical effects of chiropractic techniques on pain relief, improving flexibility, and restoring spinal motion symmetry. Obvious criticism has been directed at the physical ability to even induce movement in the horses’ back. Pilot work in three horses that were instrumented with spinal transducers attached to Steinman pins implanted into dorsal spinous processes at adjacent vertebrae demonstrated that manually applied forces associated with chiropractic techniques were able to produce substantial segmental spinal motion. The induced spinal motions were usually beyond the normal range of segmental motion that was measured during treadmill locomotion (up to 227% larger segmental spinal range of motion induced by high-velocity, low-amplitude thrusts than measured at the walk). The next logical research question would be what, if any, are the therapeutic effects of these induced spinal movements. Two randomized, control clinical trials have used pressure algometry to assess mechanical nociceptive thresholds (MNTs) in the thoracolumbar region of horses and to evaluate if chiropractic treatment can reduce back pain (or increase MNTs), compared with a control group. The first study evaluated 24 horses in active exercise, with the treatment group receiving high-velocity, low-amplitude thrusts applied to the T13 to L6 region. At the 2-week comparison, 72% (21 of 29) of sites had increased MNTs, 21% (n=6) of sites had decreased MNTs, and 7% (n=2) of sites had no change in the treatment group MNTs, compared with the control horses that had no applied treatment. The second study used 38 horses without clinical signs of back pain randomized into 5 treatment groups, with MNTs measured at 7 bilateral sites within the T9 to S2 vertebral levels. Single applications of instrument-assisted (Activator), high-velocity, low-amplitude thrusts and massage therapy were given at day 0 in two groups at sites of pain, muscle hypertonicity, or stiffness. Phenylbutazone was given orally at a dose of 2 grams, twice a day for 7 days in the third group, and active and inactive horses were assigned to two control groups. MNTs were measured at days 0, 1, 3, and 7. The day 7 median MNTs had increased by 27% in the chiropractic group, 12% in the massage therapy group, and 8% in the phenylbutazone group, with less than 1% changes in both control groups (Table 1). Future research is recommended to evaluate longer-term effects and the potential synergistic effects of combined therapies (i.e., chiropractic and massage therapy) for treating back pain.

Additional studies have assessed the effects of equine chiropractic techniques on passive spinal mobility (i.e., flexibility) and longissimus muscle tone. The first study used 10 horses to objectively measure vertical displacement, applied force, and stiffness at 5 thoracolumbar intervertebral sites in an experimentally-induced back pain model by using a randomized, crossover study design. The chiropractic treatment induced a 15% increase in vertical displacement and a 20% increase in applied force, compared with control measurements, indicative of increased spinal flexibility and increased tolerance to applied pressure. The second study measured changes in muscle tone and electromyographic (EMG) activity within the longissimus muscle immediately after spinal manipulation or reflex inhibition therapy, compared with a control group. Significant decreases in muscle tone and EMG activity were measured in both treatment groups, com-

Table 1. Summary of the Overall Percent Change in Mechanical Nociceptive Thresholds (MNTs) from Baseline (Day 0) within Treatment Groups across Days

<table>
<thead>
<tr>
<th>Treatment Group</th>
<th>Day 1</th>
<th>Day 3</th>
<th>Day 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inactive control</td>
<td>1</td>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>Active control</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Phenylbutazone</td>
<td>-9</td>
<td>-6</td>
<td>8</td>
</tr>
<tr>
<td>Massage therapy</td>
<td>8</td>
<td>9</td>
<td>12</td>
</tr>
<tr>
<td>Chiropractic (Activator)</td>
<td>-1</td>
<td>11</td>
<td>27</td>
</tr>
</tbody>
</table>
pared with no significant changes within the control group. Additional studies are needed to determine how long the increased flexibility and reduced muscle tone persist in horses treated with chiropractic techniques and if these therapies can improve performance.

The last two studies document the potential beneficial effects of chiropractic treatment on spinal movement patterns in horses with documented back pain.33,34 The first study is a case report on a dressage horse with back pain and severe loss of performance that underwent objective spinal kinematic assessment prior to and serial follow-up 8 months after the last chiropractic treatment.33 A right lateral bending restriction (functional scoliosis) was diagnosed, and two high-velocity, low-amplitude treatments were applied 3 weeks apart. Symmetry of spinal movement indices improved dramatically after the first chiropractic treatment and remained improved above baseline even 8 months after the last treatment. It was concluded that manipulation had a measurable influence on the kinematics of the thoracolumbar spine; however, this improvement was not judged equivalent to clinical improvement. A follow-up study assessed limb and spinal kinematics prior to and 1 hour and 3 weeks after chiropractic treatment in 10 horses.34 Significant changes in spinal kinematics were noted at the walk and trot, but no changes were noted in limb kinematics. The main overall effect of the chiropractic manipulations was a more flexed thoracic region, a reduced inclination of the pelvis, and improvement of the symmetry of the pelvic motion pattern. It was concluded that chiropractic treatment elicits slight but significant changes in thoracolumbar and pelvic kinematics and that some of the changes are likely to be beneficial.

12. Summary

A thorough knowledge of equine vertebral anatomy, biomechanics, and pathology is required to understand the principles and theories behind chiropractic and to apply its techniques properly. Because of its potential misuse, spinal evaluation and manipulative therapies should be provided only by specially trained veterinary clinicians or licensed human manual therapists. Anecdotal evidence and clinical experience suggest that chiropractic is an effective adjunct modality for the diagnosis and conservative treatment of select musculoskeletal-related disorders in horses. Recent research including randomized, control clinical trials support the efficacy of equine chiropractic techniques for reducing pain, improving flexibility, reducing muscle tone, and improving symmetry of spinal kinematics. Additional studies are needed to monitor the long-term changes and improvements in performance. Chiropractic provides additional diagnostic and therapeutic means that may help equine clinicians to identify and treat select musculoskeletal disorders. Chiropractic provides specialized evaluation and treatment of joint dysfunction and conservative treatment of neuromusculoskeletal disorders that currently lack treatments in traditional veterinary medicine.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Local, Segmental, and Suprasegmental Influence of Spinal Manipulation

Pedro Luis Rivera, DVM, FACFN, DACVSMR, FCoAC

1. Introduction
Veterinary Spinal Manipulative Therapy, also known as “animal chiropractic,” is a health care system that is commonly provided to patients in many veterinary practices. Because most veterinarians are not trained in this health care modality, one of the author’s goals is to describe to the attendees how to integrate this information in a clinical setting. As primary health care providers, practitioners must be able to integrate and correlate the history, primary complaint, physical examination findings, and the level of the segmental dysfunction (single or multiple). It is also crucial to understand how the stimulation of receptors affects the patient at the local, spinal cord, and suprasegmental neurological levels. To begin, recall that the nervous system is divided into the central and peripheral nervous system (CNS and PNS, respectively) and both the CNS and PNS have two halves (right side and left side) connected in the middle. Stimulation of the nervous system can occur via external receptors, internal receptors, or through the limbic system (including amygdala and olfactory cranial nerve). A simple way to stimulate the frontal cortex, which is often forgotten, is to provide an olfactory stimuli which would then affect the rhinencephalon (being part of the telencephalon) with its limbic system connections (including amygdala, among others). Evaluation of the nervous system includes assessment of the autonomic and somatic systems; please note that of these two systems, neither can be affected without affecting the other.

2. Receptors
For the body to receive or to respond to any information, it must first be equipped to interpret and transmit information. For this important task, the body relies on peripheral receptors that respond to tension, vibration, pain, temperature, or other static and dynamic stimulation. Receptors respond to stimuli by transmitting the stimulus to a peripheral nerve, leading to influencing suprasegmental or higher segmental portions of the nervous system and resulting in an action or active response. Receptors can be found in the skin, muscles, tendons, ligaments, joint capsule, and other areas. We will not discuss specialized receptors that deal with blood pressure, intestinal motility, sight, nor sound in this lecture.

Receptor classification is often based on their type (Type I–IV), individual classification (i.e., free nerve endings, muscle spindle cell [MSC], and Golgi tendon organ [GTO]), or based on types of nerve fibers...
used. This paper will briefly discuss the classification based on type of receptors and individual classification of two specific receptors crucial for the understanding of spinal manipulation, which are GTOs and MSCs.

MSCs are specialized receptors that measure changes in the length of the muscle and rate at which the muscle is contracting or elongating. The MSCs are found throughout the muscle but are found in higher concentration around the equatorial (muscle belly) region of the muscle. The MSC contains several “bags” that are found within the receptor; these are the nuclear bags and nuclear chain fibers. Nuclear bags are surrounded by another receptor called the annulospiral ring that connects to the I-a afferent fibers going to the dorsal horn. The MSC receives efferent information from the ventral horn cells (also known as lower motor neuron), allowing the muscle itself to have tone and sensitivity. The fibers that influence muscle tone and sensitivity are the α and γ motor neurons that provide what is described as “alpha and gamma gain.”11 Alpha-gamma gain describes the coactivation of said motor neurons that helps to maintain the intrafusal fiber sensitivity and muscle tone during muscle contraction. Please note that although β motor neurons are part of the lower motor neurons, they will not be discussed in this paper.

GTOs are neurotendinous receptors found at the origin and insertion of the muscle. Each GTO is innervated by a single afferent Type Ib nerve fiber. The GTO is stimulated when the muscle contracts and exerts tension on both the origin and insertion region by compressing the sensory terminals. The Ib sensory afferent fiber influences/modulates muscle contraction by stimulating interneurons and ultimately projects directly to the ipsilateral cerebellum through the spinocerebellar tracts found within the spinal cord. If the temporal summation of the GTO is high enough, then the response would be considered as an autogenic inhibition reflex (i.e., muscle contraction would decrease or stop).11

3. Trajectory of Peripheral Nerve Fibers

It is crucial and imperative for the licensed health care provider to understand the trajectory of the nerves from the intervertebral foramen to the specific receptor, as peripheral nerves contain afferent and efferent fibers (motoric and autonomic). It is not uncommon to develop what is called an “entrapment syndrome” in cases that have severe muscle spasms or extensive scar tissue formation. In essence, “entrapment syndrome” leads to a decrease in blood supply to the nerve secondary to the external pressure. Knowledge of the anatomic structures included in the cervical, brachial, and lumbosacral plexus are important to understand how chiropractic manipulation can affect the patient or impact the anticipated outcome.12–14

4. Local Changes

Professionals providing receptor-based therapies (e.g., acupuncture and manual therapies) should understand that the effect of these therapies begins at the cellular (local) level. The response to the stimulation provided at the local (cellular) level affects the individual central integrative state (CIS) of the receptors and its afferent fibers and affects the overall CIS of the cortex.

Changes at the cellular level are crucial to or responsible for maintenance of the active and constant CIS of the “connections.” All the latter changes are and should be accepted, as long as counterproductive responses such as dysafferentation and transneural degeneration (also known as neuronal degeneration) are NOT created or caused as these changes could damage the health of that cell along with its postsynaptic connections and ultimately impact the way it influences the suprasegmental and other modulatory effects, including its final efferent motoric expression.15–17

When discussing functional neurology, as it applies to spinal manipulation or other manual therapy(ies), it is critical or important for all clinicians to keep in mind the CIS (or health) of the neuronal pathways and individual neuronal systems. It is well known that neurons need several things to remain healthy and viable. These “basic requirements” include the following: oxygen, glucose (nutrition), neurotrophic factors, and correct and healthy stimulation by the presynaptic pool.15 The end result of cellular stimulation is the production of adenosine triphosphate (ATP) and protein. ATP is necessary for many cellular functions including the stimulation of the Na:K pump to help maintain adequate negative gradient and to produce proper amount of protein that is required to help with the negative cellular value and to replace and maintain “daily” cellular requirements. These cellular changes occur with proper stimulation of immediate early genes (also known as “cellular immediate early gene response”) cascade that occurs within the cytosol and the nucleus of the cell.15,16

Often, practitioners forget to assess parameters which (quantitatively) determine if the patient is exceeding its own metabolic rate, providing a window of when it would be prudent to stop or reorganize treatment protocol(s). When exceeding the metabolic rate of any neuronal connection(s), there will be decreased supplies of nutrients and oxygen, leading to downregulation of protein production. Persistent downregulation can lead to transneural degeneration/neuronal degeneration. Cells that start exceeding their metabolic rate will invariably become more sensitive to any external stimuli with the hope of trying to maintain adequate concentration of protein and or ATP, hence starting a degenerative cycle with less nutrition and oxygen and further cellular deterioration.3,4 This latter “deterioration” will invariably lead to apoptosis.
Good cellular CIS, as can be surmised, will lead to the production of healthy connections with the goal of contributing to create plasticity of those pathways. Plasticity can be described as healthy neurons making more connections between one another, strengthening a pathway or neuronal pool. Plasticity could become a double-edged sword if the neurons being stimulated are classified as small diameter fibers which carry nociceptive information.

In the field of manipulative therapy, proper or correct stimulation is the beginning to recovery! The practitioner needs to realize that overstimulation may stop recovery and make the patient prone to re-injury and/or worsening of clinical symptoms. The mechanism for how overstimulation causes damage or worsening of the clinical signs is by exceeding the “patient’s local energy resources” due to exceeding its normal metabolic rate. Assessment of heart rate, respiratory rate, blood pressure, and pupillary light reflex provide the clinician with a window assessing the balance between the parasympathetic and sympathetic system.

5. Spinal Cord
Embryologically, the CNS (brain and spinal cord) and many of its basic connections are derived from the ectodermal layer of the embryo.\textsuperscript{19,20} It is amazing how two cells (from different individuals) come together, start replicating to form a three-layer embryo (from one layer) at the same time that it elongates in a process described as “cephalization.”\textsuperscript{19,21,22} The spinal cord extends from the foramen magnum to next to the last vertebral body depending on the size and breed of the horse. Please note that each spinal nerve is composed of several rootlets that represent a somite (segment) and each segment has a dermatomal and myotomal representation. The spinal cord contains the white matter (which contain tracts) on the periphery and the gray matter (“butterfly” section and which contains cell bodies) on the center (as opposed to what is found in the cortex) with a central canal within the gray matter. The central canal is an anatomical extension of the ventricles and contains cerebrospinal fluid.

As a reminder, the gray matter mainly contains cell bodies of neurons and it is divided into four sections (dorsal/lateral and ventral horn with an intermediate column). The dorsal horn contains sensory nuclei that receive afferent sensory information. From the dorsal horn, the afferent divergent information goes to local and suprasegmental levels. The intermediolateral column and the lateral horn comprise autonomic neurons innervating visceral and pelvic organs representing the autonomic nervous system.\textsuperscript{22,23} Finally, the ventral horn contains several kinds of motor neurons that innervate specific end organs. The cell bodies found within the gray matter can be divided into the following: root cells (those found within the ventral and lateral horns and they are further divided into somatic efferent and visceral efferent), column or tract cells or commissure association cells, and, lastly, the propriospinal cells (subclassified as different kinds of “interneuron” cells), which comprise (as described by some anatomists) about 90% of all of the spinal neurons.\textsuperscript{24–26}

The white matter of the spinal cord contains myelinated nerve fibers that either ascend or descend within the spinal cord. The outer section of the spinal cord is divided into the dorsal funiculus, lateral funiculus, and ventral funiculus. There is a specific anatomical region of the spinal cord named the “ventral or anterior commissure,” which contains nerve fibers that cross from one side of the body to the other.

6. Ascending Tracts\textsuperscript{22,27,28}
Dorsal Columns–Medial Lemniscus Tract: These tracts are found within the dorsal funiculus of the white matter. They provide the body with two-point discrimination (through information provided by the Meissner, Pacinian, and Merkel Corpuscles of the region), vibration, and ultimately (once it is recognized in the somatosensory cortex among others) proprioception. This tract is described as a three-neuron connection path.

Anterolateral/Ventrolateral or Spinthalamic Tract: Please note that the description presented will be basic and simplistic. This tract is located in the ventrolateral funiculus of the white matter and carries information that deals with crude touch, temperature, and nociception (with the latter leading to the recognition of pain). This tract is also a three-neuron connection tract.

7. Spinocerebellar Tracts
Cuneo-Cerebellar Tract: Afferent information (from GTOs, joint mechanoreceptors, and some MSC) is received from the spinal levels of C8 to C1. This is a two-neuron connection tract.

Dorsal Spinocerebellar Tract (DSCT): As with the cuneocerebellar tract, these fibers carry unconscious, proprioceptive – or better described as reflexogenic information – from GTOs, joint mechanoreceptors and some MSC originating distal to the spinal cord level of T1 to L3/4 spinal cord level. As with the cuneocerebellar tract, this is a two-neuron connection tract.

Ventral Spinocerebellar Tract (VSCT): The VSCT carries information from the same receptors as the DSCT that originate in the lower extremity and trunk. This tract is also a two-neuron connection. Please note that this tract is a “special one” in which it is the only tract to the author’s knowledge that “double decussates” once at the spinal cord level and at the pontine region.

8. Basic Cortical Anatomy
Frontal lobe: Divided into primary motor, premotor, prefrontal, and supplementary motor area.

Parietal lobe: Described as the primary somatosensory area (for processing of tactile and mechan-
oreceptor transduction into true proprioception and recognition of spatial orientation).

Temporal lobe: Described as the primary auditory cortex; however, it is also involved in complex aspects of learning and memory. This lobe also has a region that in humans is crucial for the comprehension of language (Wernicke’s area).

Occipital lobe: Described as the primary visual cortex and its visual association cortex.

Limbic lobe: Will not be discussed during this lecture.

It is important to understand that ultimately, all afferent input that enters the dorsal horn, and becomes divergent, stimulates the cortex.24,25,29

9. Descending Tracts22,27,28

Descending tracts originate from different areas of the cortex and brain stem. Although one function of efferent fibers is to cause a response, it is important to understand that their main function is to modulate and control the amplitude of the response. Some of the modulation that is provided is exerted on the motor activities necessary for posture, balance, reflex activity, and muscle tone, among others.

Corticospinal tract (CST): Also known as pyramidal tracts or “volitional” tracts (i.e., deals with voluntary movements) or “final common pathway.” The cell bodies of the CST originate in the cerebral cortex at the precentral gyrus, descend through the internal capsule, cerebral peduncle, and pyramidal decussation, ending at the ventral horn or intermediolateral cell column. The division of lateral and ventral CST will not be discussed at this time.

Rubrospinal tract: These fibers originate in the red nucleus of the midbrain or mesencephalon. The axons immediately cross as they come out of the nucleus to the contralateral side of the brain, and they course through the brainstem and the lateral funiculus ultimately influencing/mediating voluntary movement. The rubrospinal tract is said to be more developed in animals (other than human primates). It is interesting to know that the rubrospinal tract receives most of its input from the reticulospinal tract originating from the red nucleus of the midbrain or mesencephalon. When the motor cortex (premotor and motor cortex) sends information to the lower motor neurons (located at the ventral horn cells and and brainstem), they send a copy to the cerebellum through the cortico-ponto-cerebellar tracts to let it know movements that are about to occur; information is also being sent from the receptors (MSC, GTO, and joint mechanoreceptors) to the cerebellum to let it know what is happening at the “present” time; and lastly, it modulates or influences the information that is being sent to the lower motor neurons (located at the brainstem and spinal cord) by sending “new suggestions” to the motor cortex to “stay in course” and in “target”. Anatomically, the cerebellum is divided longitudinally in a center section named vermis and two lateral cerebellar hemispheres, with a caudal transverse section called the flocculonodular lobe. The cerebellum is attached to the brainstem via three peduncles or “pillars” and all of them also contribute to the wall of the fourth ventricle (cranial, middle, and caudal peduncles, namely).

10. Cerebellum28,30,31

The cerebellum could be easily described as an “outpouch” or “mushroom” that arises from the pons, which develops from the metencephalon. Anatomically, it covers the cranial aspect of the fourth ventricle, and it is intimately involved in the motor control/coordination and learning (although recently, it has also been correlated to cognitive functions). The cerebellum has no major projections to the spinal cord but instead regulates movement by modulating cortical projections that influence the spinal cord. Furthermore, the cerebellum is also involved in a “feedback loop” crucial for motor movement. When the motor cortex (premotor and motor cortex) sends information to the lower motor neurons (located at the ventral horn cells and brainstem), they send a copy to the cerebellum through the cortico-ponto-cerebellar tracts to let it know the movements that are about to occur; information is also being sent from the receptors (MSC, GTO, and joint mechanoreceptors) to the cerebellum to let it know what is happening at the “present” time; and lastly, it modulates or influences the information that is being sent to the lower motor neurons (located at the brainstem and spinal cord) by sending “new suggestions” to the motor cortex to “stay in course” and in “target”. Anatomically, the cerebellum is divided longitudinally in a center section named vermis and two lateral cerebellar hemispheres, with a caudal transverse section called the flocculonodular lobe. The cerebellum is attached to the brainstem via three peduncles or “pillars” and all of them also contribute to the wall of the fourth ventricle (cranial, middle, and caudal peduncles, namely).

11. Final Thoughts

Spinal manipulation and all receptor base therapies are based on functional neuroanatomy. If it is not understood, then how can practitioners help patients improve and avoid reinjury? It is the “burden” of the trained licensed veterinarian to stand out by being able to integrate, explain, and apply said scientific information to help with the patient outcome.

Acknowledgments

Declaration of Ethics

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

Author is co-owner of the Healing Oasis Wellness Center, an accredited institution providing post-graduate state approved programs and CE seminars.

References


26. Darby, S., Cranial Cavity, Meninges and CSF. H.O.W. Center, Editor. 2009: Sturtevant, WI.


Can Acupuncture Be Used in Equine Practice?

Huisheng Xie, DVM, MS, PhD*; and G. Reed Holyoak, DVM, PhD, DACT

1. Introduction
Traditional Chinese Veterinary Medicine (TCVM) including acupuncture has been used to treat disease and relieve pain in horses for more than 2000 years. As the use of acupuncture has increased over the past few decades in countries where modern Western medicine is the foundation of health care, there has been increasing scientific effort to evaluate this ancient medical modality for objective evidence of efficacy. This paper will discuss the basis of acupuncture and evidence-based clinical application of acupuncture in equine practice including diagnosis and treatment of lameness, pain management, reproductive, and other diseases.

2. What Is Acupuncture?
While specifics will be presented below, as an introduction acupuncture comes from Greek: acus needle, pungare to pierce or to puncture the skin with a needle. It is often defined as applied stimulation at discrete and specific points on the body in order to cause a therapeutic effect. These discrete and specific locations on the body are called acupuncture points (APs) or acupoints. The defined stimulation methods are acupuncture techniques. In TCVM, acupuncture techniques include dry needling (DN) or conventional needling acupuncture, hemi-acupuncture (bloodletting), moxibustion (burning of the herb, Artemisia vulgaris, over APs), pneumo-acupuncture (injection of air under the skin), and firing acupuncture (counter-irritation with heat). In modern times, constant manual stimulation of the needles has been replaced by low current electrical stimulation (called electro-acupuncture [EA]). Aqua-acupuncture (AA; injection of injectable agents including vitamin B12 into acupoints) and gold-bead implantation (insertion of small metallic particles at certain acupoints) have been instituted and more commonly used. Also more recently, low-level lasers and static magnets are being used to stimulate certain superficial acupoints as part of acupuncture therapy.

Acupuncture Procedures
The top 3 acupuncture techniques used currently in veterinary medicine are DN, AA, and EA.

DN Technique
DN is one of the earliest acupuncture techniques. In TCVM it is called White Needle Bai-zhen (no intentional bleeding). It is the most common acupuncture treatment modality in veterinary and human practice. It involves the insertion of thin, sterile needles of certain gauges and lengths depending on species and location of acupoints.
EA

EA is a growing and common adjunct to DN treatments. Historically, EA started to be used clinically in China in the 1950s, and has become common in veterinary practices especially for analgesic purposes and other pain management. Following placement and insertion of the acupuncture needles in appropriate acupoints, the application of a mild electrical current passed through the needles allows a repeatable, more consistent, and prolonged therapeutic stimulation. The frequency and amplitude of the electrical current can be adjusted with either a high or low frequency, each having a different effect on systemic neuromodulation and the amplitude adjusted to the stimulation threshold of the patient. There are many types of EA units available with the ultimate goal of strengthening and altering the needle stimulation. Lower-frequency (around 20 Hz) EA mediates endorphin release and is best for treating pain and muscle spasms. Higher-frequency (80–120 Hz) is associated with 5-hydroxytryptamine (5-HT) release and may be best to re-educate the motor neurons in paresis and paralysis.

AA

AA involves the injection of fluids and soluble products into APs. Sterile saline, vitamin B, homeopathic remedies, the patient’s own blood, and local anesthetics are most commonly used in Western acupuncture practice. AA is used to lengthen and strengthen an acupuncture treatment. It is also used when the patient will not remain calm long enough to keep filiform needles in place. Injection of an animal’s own blood has become common for injury and autoimmune and inflammatory disorders. An interesting example of AA is highlighted in a study where 8 horses were randomly submitted to 4 different treatment protocols according to a Latin Square double-blind design in order to explore the clinical sedation effect of AA: 1) 0.1 ml kg⁻¹ of saline subcutaneously injected at the cervical region (negative control), 2) 0.1 ml kg⁻¹ of acepromazine (ACP) injected subcutaneously at the cervical region (positive control), 3) 0.01 ml kg⁻¹ of saline injected into acupoint GV-1 (AA-saline), and 4) 0.01 mg kg⁻¹ of ACP injected into GV-1 (AA-diluted ACP, or only 10% dose of ACP as compared with positive control). Signs of sedation were observed in positive control, AA-saline, and AA-diluted ACP groups at 30 minutes. Only the AA-diluted ACP was noted to have continued effect of sedation at 60 minutes after the injection. This study indicated that the saline injection in GV-1 produced sedation, and also the diluted (ACP; 0.01 mg kg⁻¹) injection at GV-1 produced an even longer sedative effect than conventional cervical injection of ACP (0.1 mg kg⁻¹).

IN-DEPTH: COMPLEMENTARY MEDICINE

3. Can Acupuncture Be Used as a Diagnostic for Lameness?

The acupoint sensitivity on palpation was reported to be used for diagnosis of lameness in horses by American equine practitioners in 1990s. Out of 327 racing Thoroughbred horses, which were examined either for lameness or routine musculoskeletal evaluation, 176 (54%) indicated the metacarpophalangeal joint pathology (MPJP) using acupuncture diagnosis. Of 176 MPJP horses, 176 (100%) had sensitive LI-18, and 158 (90%) had sensitive SI-16. Of 176 MPJP horses, 111 (63%) were not lame. Of the 65 horses that were lame, 18 (27.7%) became sound after intra-articular (IA) mepivacaine hydrochloride in the fetlock. The remaining 47 (72.3%) were lame as a result of extra-articular fetlock or non-fetlock pain.

Acupoint sensitivity on palpation was tested in horses showing signs of hoof lameness with conventional diagnosis. Sensitivity at LI-18 was found in 23/30 (77%) horses with chronic heel lameness, 31/45 (69%) acute heel lameness horses, and 24/29 (83%) laminitis horses. Sensitivity at SI-16 was detected in 18/30 (60%) horses with chronic heel lameness 27/45 (60%) acute heel lameness, and 11/29 (38%) laminitis. No correlation of foot lameness with AP sensitivity was found in this study in cases of subsolar abscess, bruised feet, hoof cracks, and painful wounds.

One hundred and two client-owned horses were presented for routine acupuncture, reduced performance, or lameness. Each horse first underwent a <2-minute screening scan of APs and was classified as positive or negative for acupoint sensitivity by the same veterinarian certified in veterinary acupuncture and experienced in performing AP scans and unaware of the presenting complaint in all cases. Then each horse was evaluated for lameness and categorized as lame or sound by a different veterinarian. In the sound group, 40/51 (78.4%) horses had a negative AP scan and 11/51 (21.6%) had a positive AP scan. In the lame group, 9/51 (17.6%) horses had a negative AP scan and 42/51 (82.4%) had a positive AP scan (P < .001). Acupuncture scanning had a sensitivity of 82.4% to detect lameness and a specificity of 78.4%, with an accuracy of 80.4%. Significant but modest correlations existed between the side of the horse that was positive on the AP scan and the side of lameness. The conclusion of the study was that an AP scan could be a useful, quick screening tool during the physical examination to identify horses that should undergo a full lameness examination and other diagnostic testing.

A Brazilian group evaluated 810 athletic horses involved in different disciplines for soundness/lameness because of poor performance, lameness, refusal to jump, upward fixation of the patella, thoracolumbar spine or sacroiliac pain, suspensory lesion, and front hoof problems from 2001 through 2012.
They used acupuncture sensitivity on palpation and clinically diagnosed 86 (9.4%) horses with stifle syndrome. Twenty-two (25.6%) of the 86 horses with stifle syndrome underwent ultrasonography and/or radiography, and lesions were detected in 21 (95.5%) horses. The diagnostic points for stifle syndrome included BL-20, BL-21, local stifle points, GB-27, SP-13, ST-30, and the sacral AP BL-54. They concluded that AP sensitivity for diagnosis of stifle disease may be considered a reliable diagnostic method and suggested it be included in routine clinical examination of horses and in reference textbooks as a lameness diagnostic modality. And finally, an equine practitioner from South Africa has reported identifying soft tissue injuries and pain in horses using diagnostic points associated the GB Channel with good clinical results.19,20

4. Acupuncture for General Pain Management and Mechanism

A recent publication reported that acupuncture analgesia mediated through increasing substances in the body including 5-HT, which increased the pain threshold, also improved the absorption of pain inducing inflammatory substances.21 Another study indicated that low-level laser acupuncture can improve the pain threshold of rabbits, goats, pigs, mice, and dogs, and increases the concentration of 5-HT in cerebral spinal fluid which suppresses the evoked cortical potential, thereby inhibiting pain.22 EA using 2.0 Hz, continuous wave, 6 volts, 30 minutes once per day for 4 weeks was stimulated at acupoints SP-10, ST-34, ST-35, Nei-xi-yan, ST-36, and GB-34 in rabbit knee osteoarthritis models. Results showed that EA reduced the levels of inflammatory factors including interleukin (IL)-1α, tumor necrosis factor (TNF)-β, and prostaglandin E2 to alleviate the inflammation reaction and also notable pain relief.23

The effect of different frequencies (2 Hz, 40 Hz, 60 Hz, 100 Hz) of EA on the pain threshold has also been studied using the goat as a model.24 Two pairs of acupoints Bai-hui and Qi-jia, Er-gen and San-yang-luo were stimulated with EA for 30 minutes. Their results showed that of the frequencies studied, EA with 60 Hz had the best effect for pain relief. Follow-up studies confirmed that EA also had an aftereffect of pain relief.25 This study indicated that after being stimulated via EA with 60 Hz for 30 minutes the pain threshold of goats increased and reached its peak at hour 0, i.e., at the end of EA stimulation. The pain tolerance then decreased gradually to the baseline by hour 5; however, by hour 6 the pain threshold began to rebound and reached a second peak at hour 8, and then gradually fell again reaching baseline at hour 12. The mean pain threshold during the time from 0 to 12 hours after EA was higher (P < .05) than that at 0.5 hours before EA, which showed that the EA-induced analgesic effect lasted for at least 12 hours in goats.25

The efficacy of various frequencies of EA for pain relief in 22 horses was systematically reviewed in a clinical trial.11 Focused radiant light/heat was used as a noxious stimulus and was directed onto the equine pastern to elicit the classic flexion-withdrawal reflex. Hoof withdrawal reflex latency (HWRL) was defined as the time (in seconds) between lamp illumination and the withdrawal of the hoof. The results indicate that the HWRL is a valid measurement to assess pain perception and to document pain relief from acupuncture. The results also suggest that EA treatments at high frequencies (120 Hz) with 30 minutes induce a stronger analgesic effect than EA treatments at low frequencies (20 Hz) with 30 minutes in local regions; however, EA treatments at lower frequencies induced longer analgesia.

A double 3 × 3 Latin Square design was applied in studying experimental lameness in six horses. Lameness was produced in each subject by tightening a setscrew against the sole of the hoof.10 Lameness grading scores of 0, 1, 2, and 3 were used to evaluate the severity of lameness. Three types of stride length were measured: total stride length, front half stride length (FHSL), and back half stride length (BHSL). The difference between FHSL and BHSL was defined as difference front/back (DFB). The DFB increased significantly when the horse was lame suggesting that the DFB could be used as an objective parameter to measure lameness in horses. EA reduced the lameness score significantly in this study. Plasma concentrations of β-endorphin, ACTH, and cortisol were measured in both of the above experiments. In addition EA significantly increased the HWRL and reduced the lameness score, and simultaneously increased the plasma β-endorphin concentration. These results indicate that the release of β-endorphin may be the pathway in which acupuncture relieves experimental pain. None of the acupuncture treatments altered the ACTH concentrations which indicates that ACTH is not involved in EA analgesia.

A different result was reported, however, in a pilot study that indicated that acupuncture treatment had no effect on pain in horses.26 Nine horses of palmar heel pain with lameness scale varied from 1 to 3 were randomly assigned to an acupuncture and control group. Twice-weekly visits on nonsuccessive days were made to each horse. Horses in the treatment group received 20 minutes of DN and EA at each visit; horses in the control group received no treatment. The same APs were applied to each horse in the treatment group (n = 5): Bai-hui, BL-11, BL-13, PC-1, HT-9, LU-1, and LU-11 with the dry needle; and SI-9 and LI-11 bilaterally with EA of 2 to 5 Hz. The researchers found with observational grading that all four horses in the control group maintained the same grade of lameness through the duration of the study or improved on one or both limbs by no more than 1 grade of lameness. Of the five horses in the treatment group,
three showed improvement of 1 lameness grade on one or both limbs, one horse did not change, and one horse’s lameness worsened through the course of the study. There was no statistically significant difference in grade of lameness between treatment and control animals at both initial and final assessment. Therefore, the researchers of this study concluded that acupuncture did not reliably modulate palmar heel pain in horses. A 2006 systematic review indicated that there was no compelling evidence to recommend or reject acupuncture for any condition in domestic animals including horses and dogs even though some encouraging data do exist that warrant further investigation in independent rigorous trials.

Different outcomes of acupuncture on lameness may be associated with the fact that lameness itself may be subjective to study. However, objective gait analyses using inertial sensors were adopted in a recent blinded and crossover study in horses. Objective gait analyses were performed before and after each treatment and at 1, 3, and 7 days after the last treatment (time points 1–9, respectively). Horses were assessed at the trot in a straight line on a hard surface and on the lunge on the left and right reins on a soft surface (conditions 1–3, respectively).

Acupuncture treatment was found to decrease hip hike difference under all conditions including condition 1: control, 6.3 ± 6.4 mm versus treatment, 0.2 ± 6.4 mm (P = .007); condition 2: control, 9.7 ± 7.8 mm versus treatment, 2.8 ± 7.8 mm (P = .032); condition 3: control, 7.3 ± 6.3 mm versus treatment, 2.7 ± 6.4 mm (P = .003). This study indicated that acupuncture treatment changed the horses’ gaits (appreciable by objective analyses), with treated horses moving in a more symmetrical manner, which suggests a lesser degree of discomfort.

5. Electro-Acupuncture Analgesia for Surgical Procedures

Electro-acupuncture analgesia (EAA) was used for surgical procedures without anesthesia drugs for the first time in 1958. EAA was conducted with the frequency of 20 Hz initially for 10 minutes and then gradually increased the frequency to 55 Hz for another 10 to 20 minutes. The frequency of 55 Hz was sustained for the entire surgical procedure. Under the EAA, multiple surgical protocols including suturing skin lacerations, subcutaneous mass excision, hernia repair, and castration have been performed successfully without drug-induced general anesthesia in 18 healthy experimental animals (10 stallions and 8 mares, from 8 to 15 years old, weighing from 350 to 450 kg) and 7 equine clinical cases (2 foals, 1 gelding, 2 stallions, and 2 donkeys). Surgeries on the head and neck, the chest wall, the thigh, and the abdomen, as well as castration were performed on experimental animals. Each animal, whether clinical or experimental, had an independent acupoints plan, depending on the site of surgery with EA stimulation throughout the duration of the surgery.

In another report, 23 surgeries in 23 cattle described the effectiveness of EA-induced surgical anesthesia/analgesia relative to regional needle placement. The locations of regional EA were divided into 4 groups: a dorsal acupoint group (Tian Ping [GV-5] and Bai Hui [GV-5]); a lumbar acupoint group: Yao Pang 1 [BL-21]; Yao Pang 2 [BL-23]; Yao Pang 3 [BL-24]; and Yao Pang 4 [BL-25], (n = 5); a combined dorsal-lumbar acupoint group (n = 8); and a control group using the last intercostal space to the femoral area as a sham point (n = 3). Surgeries performed on cattle in the dorsal acupoint group and assessed for degree of analgesia were 2 laparotomies, 3 umbilical hernia repairs and 2 castrations. Similarly, surgeries performed on cattle in the lumbar group were 5 omentopexy surgeries for correction of left-sided displacement of the abomasum, whereas surgeries performed on the dorsal-lumbar acupoint group consisted of 4 omentopexies for correction of left-sided displacement of the abomasum, 1 omentopexy for correction of right-sided displacement of the abomasum, 2 rumenotomies and 1 cesarean section. The acupoints were stimulated with currents of 2 to 6 V (30 Hz) in dorsal acupoint group, 0.5 to 2.0 V (30 Hz) in lumbar acupoint group, and 0.3 to 2.5 V (30 Hz) in dorsal-lumbar acupoint group. The results of their analyses showed that the recumbency and induction time in the dorsal acupoint group were about 10 seconds to 1 minute, respectively, and the induction time of analgesia was about 1 to 6 minutes, in all animals except 1, who failed to respond to the EA. While the induction time of analgesia in lumbar and dorsal-lumbar acupoint groups was about 10 minutes. The authors concluded that with their protocols in responsive animals that their described dorsal acupoints might be useful in providing analgesia for surgeries requiring the patient to be in a recumbent position. Whereas the use of their described lumbar and dorsal-lumbar acupoints might be useful for standing surgeries in cattle.
rectal analgesia in horses and EA produces less effect on hemodynamic and respiratory variables when compared to butorphanol.

6. Acupuncture for Treatment of Other Conditions in Horses

Back Pain
A prospective study was conducted to evaluate the use of EA in the treatment of horses with signs of chronic thoracolumbar pain. Fifteen horses were randomly allocated to 1 of 3 treatment groups. Horses in group 1 received EA stimulation (once every 3 days for 5 treatments), those in group 2 received phenylbutazone (2.2 mg/kg [1 mg/lb], PO, every 12 hours, for 15 days), and those in group 3 received 0.9% NaCl saline solution (20 mL, PO, every 12 hours for 15 days). Thoracolumbar pain scores (TPSs) were evaluated before (baseline) and after each treatment. The TPS in horses receiving phenylbutazone and saline solution did not change significantly during the study (P = .999 and P = 0.535, respectively). After the third treatment, TPS in horses receiving EA stimulation were significantly lower than baseline (P < 0.01) and decreased from 6.0 ± 0.6 to 2.1 ± 0.6. These statistically significant lower scores were maintained through followup 14 days after the fifth treatment. These results provided evidence that 3 sessions of EA treatment can successfully relieve signs of thoracolumbar pain in horses and the analgesic effect induced by EA can last for at least 20 days. Alternatively, the oral administration of phenylbutazone was not found to effectively relieve signs of thoracolumbar pain.

Another clinical trial found that EA relieved chronic back pain in performance horses. This study was a randomized, double-blind, controlled trial to evaluate EA as a treatment for back pain in sport horses. Objective measurements of pain threshold levels were obtained with a pressure algometer. Twenty-three horses with chronic back pain were divided into control (N = 7) and treatment (N = 16) groups. Trigger (painful) points were identified on each horse and baseline pain threshold measurements were taken. The control group received sham EA treatments with no needle penetration or electrical stimulation. Routine EA was performed in the treatment group using filiform acupuncture needles inserted into GV-20, GV-6, and bilaterally at BL-26, BL-54, BL-21, and BL-17. Needles were connected to 5 pairs of electrical wires and an electrical impulse (4.5 volts) was delivered at a frequency of 20 Hz for 15 minutes and 80 to 120 Hz for 15 minutes. Both sham and control EA treatments were given over the course of 5 sessions, each spaced 3 days apart and all horses were rested during the study period. After 5 treatments, pressure-induced pain was statistically significantly reduced at the trigger points in the treatment group when compared to the control group using an unpaired t-test (P = 0.034). The conclusion was that EA and rest is an effective treatment for sport horses with chronic back pain and is better than sham EA and rest over a 15-day period. Similar findings have also been reported by other researchers.

Laminitis and Navicular Disease
A study was conducted to compare lameness levels before and after acupuncture treatments in horses with chronic laminitis. Twelve adult horses with chronic laminitis received 2 acupuncture treatments 1 week apart. The points were treated using dry needling, hemo-acupuncture, and aqua-acupuncture. Lameness level was objectively evaluated using an inertial sensor-based lameness evaluation system, as well as routine examinations following American Association of Equine Practitioners scoring before the first week and 1 week after the second acupuncture treatment. Data were analyzed using Wilcoxon signed-rank test and P-values < .05 were considered statistically significant. Both the Lameness Locator (P = .0269) and routine lameness examination (P = .0039) showed a significant reduction in lameness severity. This clinical trial supports using acupuncture, along with other treatment options, in treating chronic equine laminitis.

However, another clinical trial indicated that EA for the treatment of chronic laminitis (n = 5) or navicular disease (n = 5) was not significantly different in clinical scores as compared with the control group. As the researchers of this study pointed out, the small number of animals per group may have obscured a positive effect of acupuncture. In addition, the lower frequency used in this study (5 Hz for 20 minutes using the local acupoints) may be a factor as it countered the relatively recent study in which a high frequency (120 Hz for local acupuncture) for 30 minutes induced a stronger analgesic effect than low frequencies (20 Hz) for 30 minutes in the local foot region. Other reports support the use of acupuncture for the treatment of laminitis and navicular syndrome.

Cervical Stiffness
Eighteen horses diagnosed with cervical stiffness were randomly divided into a Test group and a Control group. Horses in the Test group received 3 EA treatments (20 Hz) 7 to 10 days apart, using 1-to-2-inch needles at a standard set of APs. Horses in the Control group received treatment on the same schedule but using 0.5-mm press needles at non-APs. From each horse, 2 measurements of cervical lateral bend were taken prior to the first treatment and again 1 day after the last treatment. One measurement was the amount of bend before refusal (maximal bend, R1) and the other was amount of bend before compensation (Pre-compensation, R2). The comparison of the changes between the Test group and the Control group, based on the Wilcoxon Rank Sum test, revealed that the mean R1 change in the Test group is significantly larger than that in the...
Control group (9.83 ± 8.87 vs −6.83 ± 15.26; P = .019). The same analysis on R2 bend measurement reached the same conclusion (12.22 ± 8.82 vs −5.17 ± 13.07; P = .008). This study demonstrated that acupuncture can improve lateral bend in horses and can be an effective treatment for cervical stiffness. A group of researchers from Taiwan evaluated new acupuncture protocols for the clinical treatment of cervical spinal cord diseases in 19 dogs. The time to improvement after treatment, and recovery time were compared by DN acupuncture with or without EA. The improvement and recovery times were longer in the DN+EA group than the DN group (P < .05). Acupuncture with Jing-jia-ji was effective in cervical spinal cord diseases in different-sized dogs and in middle-aged and senior dogs. The authors concluded that the newly standardized DN methodology offers clinical practitioners an effective way to improve the outcomes of cervical neurological diseases in dogs.

Reproductive Disorders and Mastitis

The treatment of reproductive disorders and the promotion of fertility represent cornerstones of the equine and bovine industries. Acupuncture has anecdotally produced excellent results for treating mares with uterine fluid and/or urine pooling, especially older, pluriparous mares. In bovine 57 dairy cows that were diagnosed with infertility due to inactive ovaries were randomly assigned into 4 groups: EA (n = 15), AP (n = 15, hormones [n = 15] and control [n = 12]). Four acupoints used in both EA and AA groups were Bai-hui and GV-1, and bilateral Yan-chi. In the EA group an alternating frequency setting between 80 and 100 Hz was used for 30 minutes once a day for 3 consecutive days. For AA, 15 mL of 5% dextrose was injected into each of these 4 points, once daily for 3 consecutive days. For the hormone group, follicle stimulating hormone (FSH; 100–200 units per injection) was given intramuscularly twice, 48 hours apart. For the control group, no treatment was given. After treatment in the EA group, 13 out of 15 dairy cows (86.7%) showed a normal estrus, were inseminated, and 12 (80%) were diagnosed pregnant. In the AA group 9 out of 15 cows (60%) showed a normal estrus, were inseminated, and 7 (46.7%) were diagnosed pregnant. In the hormone group, 12 out of 15 (80%) showed a normal estrus, were inseminated, and 11 (73.3%) were diagnosed pregnant. In the control group, 4 out of 12 cows (33.3%) showed a normal estrus, were inseminated, and 2 (16.7%) conceived. The estrus and pregnant rates were not significantly different between the EA and hormone groups, and between the AA and control groups, but these rates in both EA and hormone groups were significantly higher than ones in the control and AA groups. In both AA and hormone groups, the milk progesterone level increased significantly after the treatment. This study indicated that EA was an effective therapy for infertility due to inactive ovaries. A clinical study demonstrated that an AA of herbals at GV-1 can prevent retained placenta in cows. One hundred twenty-four pregnant dairy cows were selected to be in an untreated control group and observed after calving to determine the retained placenta rate for the farm. Fifty-two pregnant dairy cows from the same farm were selected for the study and randomly assigned to 2 groups: 30 cows in the herbal Dang Hong Fu group and 22 cows in a saline control group. Immediately after calving, 40 mL of Dang Hong Fu (40 g of dried herbs) were injected into GV-1 in the herbal group and 40 mL of physiological saline were injected at the same site in the saline control group. Both groups were observed for retained placentas and the time until placental expulsion was recorded in the others. The retained placenta rate for the farm was not received treatment was 35.5% (44/124). The incidence of retained placenta in the Dang Hong Fu group was 16.7% and in the saline control group, 31%. The time for expulsion of placental membranes was a mean of 9 hours (range, 3.5–24 hours) in the Dang Hong Fu group and a mean of 14.7 hours (range, 3.0–24 hours) in the saline control group. When compared to the untreated control group, Dang Hong Fu AA at GV-1 significantly reduced the incidence of retained placentas (P = .047; <.05), but saline AA did not (P = .740; >.05). Herbal AA may offer an easy treatment method to reduce the incidence of retained placenta in the cow with no observed adverse side effects.

Promising human studies have prompted calls for mergers between Chinese and conventional approaches. From a systematic study involving a total of 12 clinical trials and 2177 patients, the effect of acupuncture on human male infertility was equally effective as Traditional Chinese Herbal Medicine (TCM), and its effectiveness is enhanced when applied in combination with either TCM or Western medicine. In another study, 114 human patients of in-vitro fertilization embryo transfer treated with standard long-term program at luteal phase were randomized into an acupuncture group and a control group, 57 cases in each. In the acupuncture group, at the beginning of ovulatory induction, moxibustion was applied to CV-8, and acupuncture at CV-3, CV-4, CV-6 etc. until the transfer time for 1 session of treatment. Totally, 3 sessions were required. This study indicated that acupuncture and moxibustion affect estrogen level on human chorionic gonadotropin (hCG) day, improve high-quality embryo rate, endometrial blood flow state and morphology so that the endometrial receptivity is increased. However, equine studies have had conflicting results. One of the reasons of the different results was the lack of the very important classical equine acupoint called Yan-chi which is a specific point for any infertility in horses (Fig. 1 and Table 1). Second, the practitioner must rely on the classic Chinese differentiations of specific patterns for point recommendations.
For example, ovulatory dysfunction, regardless of cause, is viewed as one of a number of possible deficiency patterns, which implies the existence of an aspect of the body that must be strengthened to achieve clinical results using acupoints including SP-6, KID-3, KID-7, and KID-10. And third, CV-4 and CV-6 in particular are among a group of points found to possess endocrine effects pertinent to reproduction, specifically ovulation in people. While several of these points can be used in the mare, other are not because access in a horse is difficult and at times dangerous, thus it is almost impossible to needle; however, other reproduction-related acupoints, in addition to Yan-chi, are effectively used, such as Shen-shu, Shen-peng, and Shen-jiao and others (Fig. 1 and Table 1).

**Stress Response**

Acupuncture has been shown to have the beneficial effect of reducing stress responses in horses. A study was conducted to compare the effects of injecting the standard dose of ACP (0.1 mg/kg, IM) with those of AA (1/10 of the standard ACP dose at the acupoint GV-1) on the stress responses of healthy horses undergoing road transport for 2.5 hours. Four different treatments were applied immediately before loading, with 8 animals/treatment: injection of saline or ACP (0.1 mg/kg, IM) at the base of the neck and injection of saline or 1/10 ACP (0.01 mg/kg) at the GV-1 acupoint. The road transport increased heart rate (HR), respiratory rate, body temperature, and serum cortisol of the untreated horses (injected with saline at the base of the neck). AA at GV-1 reduced the average HR and transport-induced increase in HR at unloading, without changing the other variables. On the other hand, ACP (0.1 mg/kg) produced significant sedation and reduced the transport-induced increase in respiratory rate but without preventing the stress-induced increase of cortisol. Similarly, sedation was induced in horses receiving a 20-minute session of DN acupuncture at GV-1, HT-7, GV-20, and BL-52 assessed by the failure to fully respond to the sudden appearance of a multicolored umbrella as a stressor.

**Emergency Resuscitation**

Acupoint GV-26, which in the horse is located just below the nostrils at the midpoint of the philtrum nasale, can be used in an emergency situation to resuscitate animals including the horse. A study of 69 cats and dogs reported that acupuncture at the acupoint GV-26 restored respiration to normal or near-normal rates within 10 to 30 seconds of needle insertion in 100% of animals if there was no concurrent cardiac arrest. When cardiac arrest occurred and vital signs were absent the revival rate was 43%. In a clinical report with patients following narcotic-induced narcosis, 243 cases in 17 different species of domestic and exotic animals and birds, acupuncture resuscitation approached the 100% efficacy reported in clinically healthy dogs. However, in animals affected with different diseases, the success of intervention was smaller (77.47%). In zoo animals suffering from narcosis, the resuscitation effectiveness achieved was 92.6%.

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**Table 1. The Commonly Used Classical Acupoints in Horses**

<table>
<thead>
<tr>
<th>Acupoint</th>
<th>Anatomy</th>
<th>Indication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bai-hui</td>
<td>On dorsal midline at the lumbosacral space</td>
<td>Lumbar pain, hindquarter pain or weakness, general calming, Yang deficiency, infertility</td>
</tr>
<tr>
<td>Shen-shu</td>
<td>2 cun lateral to Bai-hui</td>
<td>Lumbar pain, infertility, general pain management, hindquarter weakness</td>
</tr>
<tr>
<td>Shen-peng</td>
<td>2 cun cranial to Shen-shu</td>
<td>Same as Shen-shu</td>
</tr>
<tr>
<td>Shen-jiao</td>
<td>2 cun caudal to Shen-shu</td>
<td>Same as Shen-shu</td>
</tr>
<tr>
<td>Yan-chi</td>
<td>Midpoint between top of tuber coxa and Shen-peng</td>
<td>Female or male infertility, poor athletic performance, hindquarter pain/arthritis</td>
</tr>
</tbody>
</table>

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Cun is an acupuncture point measurement unit. The length of the first tail vertebra is equal to 1 Cun. The width of the last rib is equal to 1 Cun.
Metabolic Capacity
Eighteen Thoroughbred racehorses were randomly divided into 3 groups (n = 6 per group): negative control, sham aquapuncture, or positive control and acupuncture treatment groups. Horses in the acupuncture group received 5 mL distilled water injected into acupoints including Bai-hui, ST-30, ST-36, GB-27, SP-13, and BL-22 along with hemi-acupuncture (bleeding) at TH-1 and BL-67 for 6 aquapuncture sessions during the 3-week period (twice weekly). All horses had the same trainer and jockey and were submitted to at least 8 months of training and racing. The horses did not race during a 2-week period before and after the experiment. Cardiovascular values were not different between times or groups. The metabolic capacity values were statistically greater after treatment only for the acupuncture group compared with pretreatment. Creatine kinase concentrations were statistically greater after exercise for all groups, and aspartate aminotransferase concentrations were not different between times or groups. This study indicated that acupuncture increased the anaerobic metabolism of Thoroughbred horses without interference in cardiovascular performance or release of muscle enzymes in medium-load exercises.

Laryngeal Hemiplegia
Laryngeal hemiplegia (LH) is an important disease related to poor performance and upper respiratory noise in horses. While surgical procedures may be effective in young horses with grade III or IV disease, surgical procedures may be inconvenient for the treatment of LH in horses if the problems occur during the sale seasons or may be denied by some horse owners. Therefore, horse owners may try to find alternative methods for the treatment of recurrent laryngeal neuropathy. Thoroughbred horses (n = 18) referred to the acupuncture service at the Veterinary Medical Center at the University of Florida for the treatment of LH were involved in this study. All horses underwent endoscopy with left-sided flaccid laryngeal tissue that adducted during breathing noted during the exam. The hemiplegia endoscopic grades ranged from IIa to IIib. EA was performed once per week for a total of 3 to 7 times depending on the severity of hemiplegia. The acupoints used were LI-15, LI-17, LI-18, GB-21, CV-23, ST-9, SI-17, Hou-bi and Hou-shu. The EA treatment used 20 Hz for 10 minutes, then at 80 to 120 Hz for 10 minutes (Fig. 1). All horses had endoscopic examinations by independent (blinded) equine practitioners after 1 or 2 days after the last EA treatment. The endoscopic grades of hemiplegia had improved in all the horses, to between normal and grade IIb. The respiratory noise during training also appeared to be improved after the treatment.

Stem Cell
The effects of EA on the mobilization of stem cells in horses, mice, rats, and humans has recently been studied. In all 4 species, equivalent acupoints LI-4, LI-11, GV-14, and Bai-hui (or GV-20 in humans) were used with EA stimulation of 30 Hz for 45 minutes. Stimulation using EA in humans, horses, mice, and rats resulted in mobilization of mesenchymal stem cell (MSC)–like cells into systemic circulation. MSC origin of the EA-mobilized cells was supported by their ability to enhance arteriolarization of blood vessels in vivo. Mobilization of MSC-like cells was preceded by a time-dependent increase in plasma norepinephrine levels and was blocked by pretreatment with propranolol. Analysis by functional magnetic resonance imaging (fMRI) in EA-stimulated rats revealed increased functional connectivity between the anterior hypothalamus and the amygdala. Pharmacological disinhibition of these regions enhanced sympathetic activation and similarly resulted in release of MSC-like cells into the circulation. Following partial rupture of the Achilles tendon, EA produced long-lasting and powerful analgesia and generation of increased type 1 collagen content, indicative of tendon injury remodeling; however, this effect was blocked in propranolol-treated rats. Thus, EA activates the sympathetic nervous system to mobilize MSC-like cells into circulation, which can be used to enhance tissue repair and provide analgesic relief.

7. Conclusion
Acupuncture stimulation, especially EA, can release neurotransmitters such as 5-HT and endogenous opioids including β-endorphin, which appear to be the main pathways in which acupuncture relieves pain. Although the strength of the clinical trials cited above vary, acupuncture has been shown to be a viable integrative treatment for back pain, foot pain, cervical stiffness, LH, and infertility in horses. Acupoint sensitivity on palpation may be useful for the assessment of lameness along with conventional diagnostics in horses. Future well-designed studies are needed in order to strengthen the recommendation for acupuncture in the diagnosis and treatment of clinical conditions in horses.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
References and Footnote


*Lameness Locator™, Equinosis, St. Louis, MO 63104.
Tips to Improve Acupuncture Results for Lameness in Horses

Huisheng Xie, DVM, MS, PhD*; and G. Reed Holyoak, DVM, PhD, DACT

1. Introduction
Acupuncture is the most extensively researched modality under the umbrella of both traditional Chinese medicine and traditional Chinese veterinary medicine (TCVM) and has shown local, segmental, central, and autonomic effects, many of which have the potential to strongly decrease nociceptive signals and pain perception.1 It has been used for many equine clinical conditions including lameness2,3 and is also familiar to both horse owners and veterinary equine practitioners.4 This paper will review the main factors that impact the clinical results along with case examples.

Dosage of Acupuncture
Acupuncture is defined as the stimulation of specific point(s) on the surface of the body by insertion of a filiform needle, resulting in a therapeutic or homeostatic effect.5 From a TCVM standpoint, the aim is to allow Qi (vital energy or life forces) to flow harmoniously, which, for a Western practitioner, can be seen as a stimulation of the nervous system. Studies have revealed that acupoints are located in areas of sensitive neuroimmune modulation.6,7 Acupuncture analgesia is associated with the release of the neurotransmitters beta-endorphin8 and serotonin,9 and its anti-inflammatory effect is produced by regulating proinflammatory factors, including interleukin-6 and cyclooxygenase-2.10,11 These effects are closely associated with what is referred to as the De Qi responses, or the “arrival of Qi.” De Qi responses are often clinically observable myofascial or muscle fasciculations as the needle reaches the acupoint upon its insertion. Also associated are ear movement, lip movement, urination or bowel movement, and/or when the patient, sensing a neurogenic response, looks at the needle or veterinary acupuncturist. The Ling Shu book of the Huang-di-nei-jing (Yellow Emperor’s Classic of Internal Medicine) emphasizes, “The most important thing about acupuncture treatment is that the effect comes only with De Qi.”12 This basically means “No De Qi responses, no clinical results from acupuncture treatment.” These De Qi responses can be measured as the dosage of acupuncture that includes size of the needle, the depth of the needle insertion, number of acupoints used, and the length and frequency of acupuncture stimulation.

Size of Needles and Depth of Needle Insertion
Acupuncture treatment involves the insertion of thin, sterile needles with a certain size (gauge)
(Table 1) and length (Table 2), depending on species and location of acupoints.

### Size and Length of Needles

The most commonly used sizes and lengths of acupuncture needle vary depending on species (Table 1). To simplify the practice, the authors recommend using 28 gauge for all large animals, including horses, cattle, llamas, and camels, and 30 gauge for miniature horses, goats, sheep, alpacas, and pigs.

Studies have indicated that many acupuncture points can have specific effects on the body, based on the depth of stimulation. For example, acupuncture stimulation at ST-36 induced a decrease in sympathetic renal nerve activity (RNA) and mean arterial blood pressure in rats under deep anesthesia. However, acupuncture stimulation at just the level of the skin of ST-36 did not induce any change of mean arterial blood pressure and RNA. This suggests that the anatomic structures and physiologic effects of acupuncture points lie in the deeper tissues beneath the epidermis. Hence, the depth of the needle insertion impacts the De Qi, and, therefore, the outcome of acupuncture treatment, as mentioned above. The most commonly used lengths of acupuncture needle depend on the location of each acupoint and species (Table 2). For equine practice, the most commonly used needles are 1, 2, and 3 inch. One-inch needles are often used for the acupoints located at the foot, lower limbs, face, and tail; 2-inch needles are used in the area of the neck, back, shoulder, and stifle; and 3-inch needles are used for the hip acupoints.

**Tip one:** Do not use needles that are too small; they will not induce good results, as they cannot generate enough De Qi response. It is the authors' recommendation to use 28-gauge acupuncture needles of varying lengths, depending on the location of acupoints in horses.

### Number of Acupuncture Points, Duration of Each Acupuncture Session, and Frequency of Acupuncture Treatment

In general, 10 to 20 acupoints are selected for each session of acupuncture treatments, and each session lasts about 10 to 30 minutes. Unlike the “I want to see results now” mindset of many of our clients, usually three sessions of acupuncture are needed for the treatment of clinical conditions. Hence, acupuncture often takes time to see significant improvement, especially because it is commonly used for chronic diseases.

**Tip Two:** Acupuncture takes time and usually three sessions are needed for the resolution of lameness in horses.

### Common Methods of Veterinary Acupuncture and Indications

Two patients having the same disease process as diagnosed by Western medicine may be diagnosed as having two distinctly separate “pattern” diagnoses in TCVM. This is because a TCVM disease “pattern” is based on a patient’s specific personality type or “constitution,” their behavior, environmental and

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**Table 1. Acupuncture Needle Gauge, Length, and Application**

<table>
<thead>
<tr>
<th>Gauge</th>
<th>Length (mm)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>0.22</td>
<td>All small animals: cats, rabbits, small dogs, avian, and small exotics</td>
</tr>
<tr>
<td>32</td>
<td>0.25</td>
<td>Goats, sheep, alpacas, and dogs</td>
</tr>
<tr>
<td>30</td>
<td>0.30</td>
<td>Goats, sheep, alpacas, dogs, horses, cattle, llamas, and pigs</td>
</tr>
<tr>
<td>28</td>
<td>0.35</td>
<td>All large animals: horses, cattle, llamas, pigs, elephants, and camels</td>
</tr>
<tr>
<td>26</td>
<td>0.40</td>
<td>All large animals: horses, cattle, elephants, and camels</td>
</tr>
</tbody>
</table>

**Table 2. Acupuncture Needle Length and Application**

<table>
<thead>
<tr>
<th>Length</th>
<th>Application by Animal</th>
</tr>
</thead>
<tbody>
<tr>
<td>13</td>
<td>Goats, sheep, alpacas, pigs: head, feet, lower limbs, ears, tail, front-mu (alarm) points</td>
</tr>
<tr>
<td></td>
<td>Horses, cattle and llamas: ears/eyes, feet</td>
</tr>
<tr>
<td>25</td>
<td>Goats, sheep, alpacas, pigs: neck, shoulder, limbs back-shu (association) points</td>
</tr>
<tr>
<td></td>
<td>Horses, cattle and llamas: feet, lower limbs, head, tail, front-mu points</td>
</tr>
<tr>
<td>40</td>
<td>Goats, sheep, alpacas, pigs: hip, shoulder</td>
</tr>
<tr>
<td></td>
<td>Horses, cattle and llamas: back-shu points, limbs</td>
</tr>
<tr>
<td>50</td>
<td>Goats, sheep, alpacas, pigs: hip</td>
</tr>
<tr>
<td></td>
<td>Horses, cattle and llamas: neck, shoulder, stifle, lumbosacral, hip</td>
</tr>
<tr>
<td>75</td>
<td>Horses and cattle: hip</td>
</tr>
<tr>
<td>100</td>
<td>Horses and cattle: hip</td>
</tr>
<tr>
<td>150</td>
<td>Horse: hip</td>
</tr>
</tbody>
</table>
dietary impacts, as well as clinical presentation and pathologies. Therefore, each patient would be treated differently with TCVM according to its specific disease pattern, whereas in Western medicine, they would be treated identically based solely on their clinical signs.17 Four main patterns include two pairs, excess vs deficiency and heat vs cold. Excess and deficiency patterns refer to the opposing forces between the body’s resistance and pathogenic factors during the course of a disease. As an example, an excess pattern could present as erythema with a serous exudate, whereas a deficiency pattern may present as dry flaky skin. Cold and heat patterns are used to determine the nature of a disease through the clinical signs of an imbalance of the body’s warming and cooling powers.18 For an example with these patterns, intuitively, a heat pattern would present as localized or systemic pyrexia, often with cool-seeking behavior; and a cold pattern as inadequate blood flow in the extremities, such as cold ears and legs, with heat-seeking behavior. Some acupuncture methods are good at treating excess or heat, whereas others are good at deficiency or cold.

Dry Needle
Dry needle (DN)12 is the most commonly used technique and involves the insertion of fine, sterile needles into specific anatomic areas of the body (“acupoints”). Mechanical stimulation can be applied to the needles manually if electroacupuncture (EA) is not available and if the patient tolerates it.

Indications
DN is one of the oldest acupuncture methods and can be used in treating any pattern.

Cautions and Contraindications
Caution is warranted in placing needles in the acupoints around the abdomen, as they are not easily accessed in horses and are often associated with reflexive kicks. In addition, in pregnant mares BL-67, SP-6, ST-36, ST-40, LIV-3, and LI-4, as well as the points around abdomen, should be used with judgment and skill.

Electroacupuncture
EA19 involves the use of a mild electrical current by attaching electrodes and applying a mild electric current to the needles. EA enables deeper penetration of electric energy into the percutaneous and muscle tissue and promotes a more profound local and systemic analgesic response.

Indications
EA is often used for heat patterns such as high fever; for excess patterns including pain management, lameness, colic, and impaction; and for deficiency patterns including diarrhea, infertility, and facial or radial nerve paralysis.

Cautions and Contraindications
Caution is needed in using EA in cases with seizures, neoplasia, a pace-maker, or pregnancy. It is also a time-consuming protocol and thus may not be the first choice for a busy equine practitioner.

Aqua-Acupuncture
Aqua-acupuncture (AA)20 sometimes called pharmacopuncture, involves the injection of sterile liquids into acupuncture points in order to stimulate the point. AA may provide a prolonged stimulus at the point. Mildly caustic or autologous substances (i.e., blood) can also be used. Commonly used substances include saline, polysulfated glycosaminoglycans, vitamin B complex, and vitamin B-12.

Indications
AA is often used for myofascial or muscle pain, muscle atrophy, anorexia, and diarrhea.

Cautions and Other Comments
Because AA is simple, relatively quick, with easy-access, it is one of the most popular acupuncture methods used in equine practice.

● Tip Three: If aqua-acupuncture, which is the most convenient method, cannot produce the desired result, electroacupuncture can be the back-up method.

Moxibustion
Moxibustion21 involves the heating of either an acupuncture point or a needle inserted into an acupuncture point with moxa, a type of bundled herb consisting of Artemesia (mugwort). Modern research indicates that the mechanisms of moxibustion mainly relate to the thermal, radiation, and pharmacological effects of moxa and its combustion products at the acupoint.

Indications
Moxibustion is good for cold and deficiency patterns, such as chronic arthritis, back pain, and poor digestive and absorptive conditions.

Cautions and Contraindications
Moxibustion should not be used for a heat pattern.

Low-Level Impulse Light Amplification by Stimulated Emission of Radiation (LASER)
This is the stimulation of an acupuncture point using a low-level impulse laser.22

Indications
It is effective for an open wound or nonhealing wound. It can be used in the acupoints in the area such as feet where the skin is thin and horses hate to be needled.
Cautions and Other Comments
The results for the acupoints near the area where skin is dark colored or thick may not be as desired, in that the laser may not be able to penetrate deeply enough. However, the penetration may be improved if the skin is precooled with ice or clipped.

2. List of Top Acupoints for Commonly Seen Lameness
There are over 300 transpositional and over 150 classical acupuncture points in horses. In TCVM, a Western medical diagnosis may present different patterns due to differences in a patient’s personality, constitution, environmental, and dietary impacts. Therefore, each patient should be treated differently according to a specific pattern. However, it takes a lot of training to be capable of differentiating each pattern based on the TCVM examination, including tongue and pulse diagnosis. The information below is in a cookbook-style outline of suggested acupoints for various disease entities with the intent to introduce a simple protocol for the listed clinical condition. To provide a more refined treatment with maximal effect, veterinarians should consult a certified veterinary acupuncturist or certified TCVM practitioner for a more accurate or detailed pattern differentiation and should treat each patient with acupuncture and Chinese herbal medicine accordingly.

Acupuncture for Foot/Hoof/Heel Pain
- Use DN or EA at the top 5 local points: PC-9, Qi-ti-men, LI-3, SI-3, and TH-1 (Fig. 1).
- Add DN LU-11 when BL-13 is sensitive.
- Add DN LI-4 if LI-18 still sensitive.
- Hemoacupuncture LI-1, SI-1, and TH-1 for acute laminitis.

Acupuncture for Shoulder Pain
- DN: SI-1, SI-3, TH-1, and LI-3 (Fig. 2).

3. Case Study
Case Example 1
A 10-year-old Thoroughbred gelding presented with acute onset of laminitis of both forefeet one week after prosthetic laryngoplasty. He had a history of white line disease in both front feet. Radiographic evidence showed that the distal phalanx of both thoracic limbs had rotated by roughly 10 degrees. The horse was pyrexic and was being treated with 2 grams phenylbutazone orally twice a day. On examination, the gelding’s constitution was Wood. He was 4/5 lame on the left thoracic limb, and 5/5 lame on the right thoracic limb. His tongue was dark purple and his pulse wiry. The acupuncture points LI-17, LI-18, PC-1, and BL-13 (5/5) were sensitive bilaterally. A TCVM diagnosis of both front feet was Qi-blood stagnation and liver damp heat, based on his history, his dark purple tongue, wiry pulse, and sensitivity on diagnostic points. Treatment for this case included the following:

Acupuncture
- DN: Bai-hui.
- HA: TH-1, LI-1, and SI-1 with 25-gauge hypodermic needles.
EA: 20 Hz 20 minutes at the following 7 pairs of points, one session per week for 3 weeks: Shen-shen, bilateral; bilateral GB-21 + BL-11; bilateral Qian-ti-men + LI-3; and bilateral PC-9 + SI-3.

Outcome
The gelding became less lame (lameness 2/5 in both front limbs) and was comfortable enough to move around in the pasture after 3 weekly acupuncture treatments. The horse was totally sound and galloped in the pasture after another 3 biweekly acupuncture treatments using DN and EA at the same points described above. Since then, the horse has become a pleasure riding horse and has had no foot lameness for the past 11 years at the writing of this paper.

Tip Four: Aggressive acupuncture treatment, as in multiple sessions per week, can be used effectively for the treatment of acute laminitis in horses.

Case Example 2
A 20-year-old Quarter Horse gelding presented with chronic back pain of 1-year duration. While being ridden, he would swing his right pelvic limb laterally and kick out. He had a history of right hock osteoarthritis. Corticosteroid injections into the hocks did not appear to improve the condition. The referring veterinarian had also diagnosed equine protozoal myeloencephalitis (EPM) based upon analysis of the cerebrospinal fluid. After 3 months of EPM medication, the horse seemed more alert but would still side-kick during rides. Extensive massage (each session lasting several hours) of his back and hip provided mild relief. Saddle changes gave no relief. The horse was a typical Earth constitution and tolerated any type of treatment well (e.g., dental work, injections, shoeing, and acupuncture needling). He had remained generally healthy his entire life, except for side-kicking. As a pleasure riding horse (jumping and trotting), he was ridden about three times a week for about an hour each time.

Fig. 2. Acupoints for the treatment of most commonly seen lameness conditions in horses (Huisheng Xie, TCVM Atlas, Reddick: Florida, Chi Institute, 2015).
On TCVM examination, the gelding appeared alert with good Shen (mentation). His tongue was purple, and his pulse was deep and fast. On acupuncture point palpation ("scanning"), he was very sensitive (4/5) over points BL-13 through BL-21 on both sides. The points BL-38, BL-39, BL-53, and BL-54 were mildly sensitive (2/5) on palpation. The TCVM diagnosis for this gelding was Qi stagnation of the back and secondary stagnation in the pelvic limbs. Treatment included the following:

Acupuncture

- One session every 3 to 5 weeks for a total of 3 treatments.
- DN: Bai-hui, BL-67, GB-44, and BL-60.
- EA (at 20 Hz for 20 minutes) at the following six point pairs: Shen-shu + Shen-shu; BL-15 + BL-15; BL-18 + BL-18; BL-21 + BL-21; BL-40 + BL-40; and BL-54 + BL-54.
- AA (5 ml of vitamin B12 per point): Hua-tuo-jia-ji along BL-17 to BL-21.

Oral Herbal Medicine

Modified Shen Tong Zhu Yu Tang\textsuperscript{b} at 15 grams twice daily for 45 days.

Outcome

After two acupuncture treatments and 7 weeks of daily herbal medication, the horse’s back pain and side-kicking behavior were 80% improved. After one further acupuncture treatment, these problems were clinically resolved. The previous rider and horse owner (her body weight was around 250 lb) had been encouraged and sent this horse to her niece (weighed about 100 lb) as a pleasure riding horse. Subsequently, the horse enjoyed 8 years more of pleasure riding and had no recurrent back pain before being retired to pasture as a sound horse.

- Tip Five: Back pain can be caused by a rider or saddle. These factors must be considered as part of your diagnosis and treatment of a sore back in horses.

Case Example 3

A 16-year-old Thoroughbred broodmare presented with severe pelvic limb lameness. During her racing career 10 years earlier, she had had a history of a hip fracture and tendonitis. After retirement from racing, she produced three foals from normal pregnancies. On TCVM examination, the mare’s lameness grade was 4/5 in her right hind limb. On her right side, BL-54, BL-53, Lu-gu, Huan-tiao, and Huan-hou were very sensitive (4/5) on palpation. Her constitution was Earth. Her tongue was purple, swollen, and wet, and her pulse was deep and weak. The mare had desirable genetic traits; therefore, the goal was to make her sufficiently comfortable and prepared for the next breeding season. The TCVM diagnosis was Qi blood stagnation of the hip with kidney Qi deficiency. Treatment included the following:

Acupuncture

- One session per month for a total of 3 treatments.
- EA (at 20 Hz for 20 minutes) at the following six point pairs: Shen-shu + Shen-shu; BL-54 + BL-54; BL-40 + BL-35 bilaterally; Left BL-38 + SP-12; and Right Lu-gu + GB-29.

Oral Herbal Medicine

Modified Shen Tong Zhu Yu Tang\textsuperscript{b} at 15 grams twice daily for 3 months.

Outcome

The mare became pasture sound after three acupuncture treatments and 3 months of daily herbal medication. At this point, treatment of the infertility due to kidney Qi deficiency was initiated. The mare was prescribed Sheng Jing San\textsuperscript{2} at a dose of 30 grams orally twice daily for 2 months. As a result, the mare went on to produce a further six foals before she was retired to pasture at the age of 23 years.

- Tip Six: Infertility in mares might be caused by pain. Pain must be resolved first before considering fertility.

Case Example 4

An 11-year-old Dutch Warmblood gelding used for dressage and jumping competitions presented with significant lameness of the right pelvic limb. Four months earlier, he had run into a tree, injuring the right hind limb but had appeared to recover after 4 months of rest. However, when the rider started to train the horse again, the lameness recurred. Initially, oral phenylbutazone\textsuperscript{a} relieved the lameness, but 6 days later, the horse presented to a conventional veterinarian with a grade 3/5 right pelvic limb lameness being unresponsive to the drug. Injections of local anesthetic into the right hock joint did not improve the lameness and no abnormalities could be detected via radiography, magnetic resonance imaging, or scintigraphy. The gelding was then referred for acupuncture. On TCVM examination, the horse was assessed to have a Wood constitution with adequate quality Shen. His pulse was wiry and his tongue purple. His caretaker described him as a good athlete who loved to run and compete and also as being dominant and aggressive towards other horses. On the left, LI-15 to 18 (3/5), BL-13 to 21, and BL-54/Lu-gu (2/5) were sensitive. On the right, BL-13 to 21, BL-39 (2/5), and BL-54/Lu-gu (4/5) were sensitive. The horse’s TCVM diagnosis was, therefore, Qi and blood stagnation of the right hip and back. Treatment included the following:

\textsuperscript{a}AAEP PROCEEDINGS / Vol. 64 / 2018 335
Acupuncture

- DN: BL-67, GB-44, left LI-1, and left LU-11.
- EA (at 20 Hz for 20 minutes) at the following five point pairs: Shen-shu + Shen-shu; BL-54 + BL-54; Shen-jiao + Lu-gu; Right BL-53 + BL-35; and Right Da-kua + Xiao-kua.

Oral Herbal Medicine

Modified Shen Tong Zhu Yu Tangb at 30 grams twice daily for 2 weeks, followed by 15 grams twice daily for 2 months.

Outcome

This horse received only one acupuncture treatment. Six weeks later, he had returned to work and the lameness was 95% improved. Later, the horse had a colic episode that was resolved by TCVM. He also had an episode of anhidrosis, which too was resolved by TCVM, after which the horse with his owner was 100% sound for a high-level competition.

4. Conclusion

Acupuncture is relatively safe and also effective for the treatment of lameness when practiced by skilled, accredited practitioners. Its clinical results depend on dosage of acupuncture (number of acupuncture points, depth of needle insertion, frequency, and duration), type of the acupuncture methods, and pattern diagnosis.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Ethics of the AVMA.

Conflict of Interest

Dr. Huisheng Xie is one of the owners of Chi Institute of TCVM and Jing-Tang Herbal, Inc.

References and Footnotes

Evidence-Based Evaluation of Acupuncture as a Complementary Modality for Chronic Equine Laminitis

Kevin J. May, DVM, CVA*; Dongbin Lee, DVM, PhD; Fanglong Dong, PhD; and Babak Faramarzi, DVM, CVA, MSc, PhD

Acupuncture treatment can improve the lameness and pain in horses suffering from chronic laminitis. Acupuncture can be performed along with other treatment options and should be considered in horses suffering from chronic laminitis. Authors’ addresses: 13997 Whispering Meadows Lane, Jamul, CA 91935 (May); College of Veterinary Medicine (Faramarzi, Lee); Graduate College of Biomedical Sciences (Dong), Western University of Health Sciences, 309 E Second St., Pomona, CA 91766-1854; e-mail: kjmaymsi@cox.net. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Due to its associated severe pain and lameness, laminitis has widespread implications when it comes to the welfare of the horse. A previous study revealed that 13% of horse operations and owners reported laminitis-related problems annually,¹ and 50% of laminitic horses referred to veterinary teaching hospitals were eventually euthanized.² Although several theories have been presented, knowledge of laminitis etiology and pathogenesis is limited and, thus, so are the treatment options.³ Although traditional Western medicine has not been very successful in treating laminitis, there is circumstantial evidence that acupuncture reduces the patient’s lameness and suffering; however, evidenced-based scientific research is scarce.⁴ Many recent studies have focused on the effect of acupuncture in treating other equine diseases such as gastrointestinal and reproductive disorders, but there is a lack of evidence-based research supporting the efficacy of acupuncture in treating laminitis.⁵ The purpose of this study was to objectively evaluate the effect of acupuncture treatment on the lameness level seen in horses with chronic equine laminitis.

2. Materials and Methods

Twelve adult horses with chronic laminitis, varying in age, breed, sex, initial cause, and degree of lameness and length of clinical signs, were recruited for this study. During the evaluation and treatment period, no alterations were allowed in any of the supplements, medications, shoeing, or management of these horses. Allowing no alterations permitted focusing the study on the impact of the applied acupuncture. Laminitis was diagnosed by the referring veterinarians via radiography and clinical examination at least one month before the acupuncture treatments. A diagnostic acupuncture palpa-
tion examination (DAPE) was performed on all horses. The acupuncture treatments included dry needling, hemo-acupuncture, and aqua-acupuncture, depending on the nature of the problem and the location of the acupuncture points treated. For consistency, hemo-acupuncture (Triple Healer 1, Small Intestine 1, Large Intestine 1, QIAN-TI-TOU, and QIAN-TI-TOU mirror point) and dry needling (Lung 11, Pericardium 9, Heart 9, QIAN-TI-MEN points) were used as the basic treatment formula for all the horses in this study, with other acupuncture points added as indicated by the DAPE.

Each horse received two acupuncture treatments, one week apart. While acupuncture treatments were performed by one veterinarian, all lameness examinations were performed by another veterinarian. In addition to a routine visual lameness examination (following AAEP grading), an objective lameness examination was also performed using a wireless, body-mounted inertial gyroscope and accelerometer system. Lameness examinations were performed before and 10 minutes, one day, and one week after each acupuncture treatment.

The lameness levels between each measurement were statistically analyzed via calculation of paired t-test and Wilcoxon signed rank test with P values <0.05 considered statistically significant.

3. Results

The statistical differences among the lameness levels at each lameness examination were evaluated. Data revealed that one week after the second acupuncture treatment, the degree of lameness was significantly reduced (P = 0.027) from baseline (before first acupuncture treatment). Moreover, the level of lameness 10 minutes after the second acupuncture treatment significantly decreased (P = 0.042) compared with 10 minutes after the first treatment.

The DAPE results varied with no set pattern of diagnostic points revealed for patients with chronic laminitis.

4. Discussion

Due to a lack of strong research studies and a growing interest in holistic medicine from both clinicians and clients, there is a great need for advancing research in veterinary acupuncture. The results of this study support the anecdotal evidence that acupuncture can alleviate the level of lameness and pain and that more than one acupuncture treatment is significantly effective in horses with chronic laminitis. Acupuncture works by modulating function throughout different levels of the nervous system. It influences several organs and tissues that are commonly involved in laminitis, such as those in the musculoskeletal, gastrointestinal, and immune systems. The complex nature of laminitis suggests acupuncture as an appropriate treatment, as acupuncture influences several body sys-tems and modulates complex pathways. As the results of this study have shown, in chronic laminitis, acupuncture can be effective in treating myofascial pain syndromes that normally do not respond to routine conventional therapies. Acupuncture treatments do not interfere with other treatments (e.g., therapeutic shoeing, medications, and dietary restrictions); thus, it can be offered simultaneously as a complementary modality for chronic laminitis.

Like any other study, this study suffered from several limitations. Given the limited number of horses in this current study and the fact that laminitis has a multifactorial and complicated etiology and pathophysiology, it was not possible to utilize a significant number of horses with the same etiology and severity. This limitation also applied to using horses of the same breed and sex and similar age. Thus, given these limitations, it was not possible to include a control group. This study offered two acupuncture treatments, one week apart, and the lameness examinations were performed before the first treatment until one week after the second treatment. Nonetheless, further research is needed to determine the optimum number and frequency of acupuncture treatments to achieve the maximum benefit of this modality for this condition, as well as how long the therapeutic effects of the acupuncture continue after the last treatment. Our data suggest that acupuncture is effective in improving lameness in horses with chronic laminitis.

Acknowledgments

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Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA. This study was approved by the Institutional Animal Care and Use Committee (IACUC) and horse owners’ consents were obtained.

Conflicts of Interest

The Authors have no conflicts of interest.

References and Footnote


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Examination of the Equine Foot

Tracy A. Turner, DVM, MS, DACVS, DACVSMR

1. Introduction
The equine foot is the most common site for lameness to develop. It is therefore of utmost importance to perform a thorough examination of the foot to identify problems or predisposing factors that need discussion with the prospective buyer.

There are numerous causes of pain in the foot of the horse. These causes can be categorized as the following: (1) conditions of the hoof wall and horn-producing tissues, (2) conditions of the third phalanx, and (3) conditions of the podotrochlear region. Hoof problems would include hoof wall defects, such as cracks that involve the sensitive tissue; laminitis, laminar tearing (local, due to hoof imbalance), and separation or inflammation of the sensitive laminae from the insensitive laminae; abscess formation; contusions of the hoof causing bruising or corn formation; neoplasia; and pododermatitis (thrush or canker). Third phalanx problems include fractures of the coffin bone (types I–VII), deep digital flexor insertional tendinopathy, pedal osteitis (generalized or localized inflammation of the bone), and disruption of the insertions of the collateral ligaments, cyst-like lesion formation, and remodeling disease. Conditions of the podotrochlear region have been reported to include distal interphalangeal synovitis/capsulitis, deep digital flexor tendinitis, desmitis of the impar (distal navicular ligament) or collateral sesamoidean ligaments, navicular osteitis or osteopathy, vascular disease of the navicular arteries, and navicular fractures. The common denominator of all these conditions is that they are characterized by pain that can be localized to the hoof.

2. Examination
The examination requires comprehensive evaluation of the external hoof, radiographs or other imaging modalities, and “hoof balance,” and evaluation for deep pain. The evaluation of the horse’s foot, like all examinations, requires a thorough medical, performance, and shoeing history.

An appreciation of the breed and the use of the horse will provide information relative to the incidence of certain foot problems. Thoroughbred and Quarter Horse racehorses have a relatively high incidence of foot bruising, pedal osteitis, distal phalanx fractures, heel bulb damage from overreaching, quarter cracks, nail problems, and underrun and sheared heels. Standardbred racehorses also have similar foot problems but have a much higher incidence of quarter cracks. Racing combines extraordinary speed with surfaces that are more conducive to speed rather than cushion, thus creating tremendous force on the hoof. Quarter Horses, Thoroughbreds, Standardbreds, and the warmblood breeds have the highest incidence of navicular problems, whereas Arabians and ponies have the least issue with the navicular bone. Horses that participate
in agility sports such as roping, cutting, reining, barrel racing, and polo have frequent problems with pulled shoes and associated hoof wall loss. Distal phalanx fractures occur but with less frequency than in racing. Palmar foot pain syndrome is a frequent diagnosis in this group as well. Horses used over fences such as show jumpers and eventers suffer frequently from foot bruising, pulled shoes and hoof wall loss, quarter cracks, and palmar foot pain syndrome. Gaited horses such as Morgans, American Saddlebreds, Tennessee Walking Horses, Arabians, and Hackneys (horses and ponies) are often purposely shod with longer hooves, heavier shoes, and pads, which alter the biomechanics of the hoof capsule for animation and frequently result in problems with hoof wall breakage, hoof cracks, and thrush. Sand cracks (coronary quarter cracks) occur more often in Saddlebreds and Tennessee Walking Horses than any other breed. Laminitis is seen frequently in older horses of all breeds, Morgans, ponies of all breeds, and heavily campaigned overweight show horses. Horses that are turned out to pasture for extended periods of time frequently show hoof wall loss, superficial hoof cracks, and subsolar infections. The larger draft breeds (Clydesdales, Percherons, Belgians) that work in harness often injure the coronet and associated tissues by stepping on their feet. There is reportedly a high incidence of canker in these draft breeds.

3. Physical Inspection

Evaluation of the hoof begins with a subjective evaluation of the size, shape, toe length, and heel length of the hoof, as well as evaluation of hoof/pastern axis and position of the limbs relative to each other. The examiner should evaluate the shoes if the horse is wearing them and inquire why any special shoe or additions to a shoe (calk, grabs, extensions, or bars) were used. Bar shoes, for example, are often useful in treating various foot problems but may be used solely as a fad (all the dressage horses in a barn wear egg-bar shoes). Is the bar shoe fitted appropriately? First and foremost, it is more important how any shoe is applied rather than the type of shoe (i.e. “the application is more important than the appliance”).

Like any physical examination, the hoof examination is more than simply measuring a few parameters and determining where on the scale of normality they fall. Instead, it should be a systematic evaluation of the hoof capsule and the structures within, reflecting the general health of the hoof, the stresses that have been placed on it, and the hoof’s response to these stresses. The hoof is a dynamic structure that grows continuously and, therefore, has the ability to deform continuously to stresses that are applied to it.

The examination begins simply by looking at the hoof, preferably from sufficient distance to compare all four feet at once. The size, shape, toe length, heel length, hoof pastern axis, and position of each foot relative to the limb and to each other, are assessed. This is the best time to evaluate the horse’s “balance,” which can be explained as the differences in each of the horse’s legs and how the horse stands on the hoof, evaluating the position of the hoof on the end of the limb. This analysis must be performed from 3 directions: the front (dorsal), the side (lateral), and the back (palmar/plantar). From the front, the hoof needs to be assessed for symmetry and alignment. Is the hoof centered under the cannon bone or is it offset? If the hoof is offset, then the stresses on the hoof will change. Does the hoof rotate on the leg (toe-in or toe-out)? If it does rotate, where does it rotate from, knee, fetlock, pastern, or hoof? This will determine where the torque is occurring on the hoof. Does the ground surface of the hoof appear symmetrical? If not, this indicates stresses on the hoof. Most commonly, one sees that the medial wall is more upright. Is the coronary band straight and parallel to the ground surface? If not, this indicates a stress on the wall below the coronet.

The next factor to observe is hoof alignment. This is viewed from the dorsal and lateral aspects. Most horses (60%) will have a hoof angle between 50–55 degrees. The hoof axis describes how the cannon bone, pastern, and hoof align. Ideally, when the horse is standing square, the cannon bone, pastern, and hoof should form a straight line as seen from the front. From the side, the pastern and hoof should be parallel with the angle created by the dorsal hoof wall and the angle of the heels should be within 5 degrees of the angle of the toe. Horses that have a low hoof angle compared with the pastern have a broken-back hoof axis and fall into a group of horses called long toe and low heel. On the other hand, horses with a steep hoof and sloping pastern have a broken-forward axis and are called “clubby.” Unfortunately, horses do not normally stand with their cannon bones perfectly perpendicular to the ground, so evaluation of hoof alignment must be done with the horse standing comfortably. The purpose is not to determine right and wrong but to determine what is comfortable for the horse.

The next areas to evaluate are the shape and levelness of the hoof. Generally, the front hoof should be round or circular in shape, while the rear hoof is more triangular or “pear” shaped. Front and rear hooves should be shaped like inverted cones. Both hooves should be evaluated for differences in length and width. Hooves of equal width and length tend to look circular, but as the length becomes greater than the width, the hoof wall in the quarters becomes more upright and the stresses on the hoof will naturally be different. The levelness of the hoof has two aspects: the ground-bearing surface should be flat and perpendicular to the upper limb. This determines how evenly the hoof wall will bear weight and how the leg is loaded during weight bearing. These factors are the basis for determining medial to lateral hoof orientation.
The final observation is the evaluation of heel support. This is best performed from the side and back of the hoof. This is done by assessing the conformation of the ground-bearing surface of the heels relative to the remaining hoof capsule, pastern, fetlock, and cannon bone. Does the ground-bearing surface provide sufficient support to the palmar (plantar) aspect of the digit? Are the heels of the hoof centered under the cannon bone (from the palmar/plantar aspect) or are they offset? This can be important in determining how the horse loads the heels, whether both sides are landing simultaneously, or whether one heel may strike before the other. These observations are helpful for the examiner to interpret how the hoof capsule has grown and remodeled to adapt to the forces on it.

The next stage of evaluation needs to be performed first with the horse in weight-bearing position and then with the foot in non-weight-bearing position. This begins by palpating the pastern for any obvious heat, pain, or swelling. The examiner also needs to palpate the bones and tendinous structures. Generally, the flexor tendons are not as wide as the pastern bones and there is a finger’s width difference medially and laterally. The tendons should be followed down the leg until they disappear at the heel bulb.

The digital arteries, vein, and nerve are palpated next. It is normal to feel a digital pulse but not a bounding pulse, which is abnormal and an indicator of foot inflammation. The strength of the pulse can be compared with other limbs to enhance interpretation. A symmetrical abnormal pulse indicates generalized inflammation, whereas an asymmetric pulse indicates an inflammatory process on the side of the stronger pulse. In addition, the skin should be carefully palpated for the presence of neurectomy scars.

Palpation is then continued to the coronet (hairline/hoof capsule junction). The author prefers to palpate from the central toe region caudally on the line/hoof capsule junction). The author believes that these edges indicate a proximal movement of the hoof capsule (“jamming”) into the hairline. In many breeds, particularly in the gaited breeds that carry longer lengths of hoof, this seems to be normal. As the edge becomes more prominent, the examiner can be sure that the vertical distance from the hairline to the extensor process of the third phalanx is increasing (measurement that can be confirmed with a lateral radiograph).

From the coronet, the examiner moves to the collateral cartilages, which should be palpated and manipulated. The palmar and proximal edges should be easily defined. The thickness, density, and pliability of the cartilages need to be assessed. Palpation of this area not only will determine if there is any pain but also can give an impression of the flexibility of the hoof. For instance, a very stiff, inflexible collateral cartilage is associated with a narrow, upright hoof. On the other hand, flimsy cartilages are commonly seen in the hoof with collapsed heels and a narrow, convex-shaped frog.

The entire hoof wall must be examined for the presence of cracks, fissures, bulges, growth abnormalities, focal heat, wall loss, or breakage. A high percentage of quarter and heel cracks begin as small very fine fissures at the coronet. They may extend less than 1 cm distally and are easily missed if this area is not carefully examined. In fact, the author pays particularly close attention to any area of the hairline that is not straight. These small fissures are a definite cause of foot pain and are usually associated with deeper injury to the coronet and/or lamina below. Concentric rings on all four hoof walls usually indicate metabolic stress, such as fever or significant diet change. Divergent rings most often indicate laminitis.

The exit of all shoeing nails from the hoof capsule needs to be evaluated. The higher the exit point, the more likely the nail is impinging on sensitive tissue. This is an excellent time to use the hammer and gently percuss the hoof wall to determine wall defects, hollow sounds, or painful areas.

From this point, it is natural to begin manipulating the foot in the non-weight-bearing position. Begin by cleaning the bottom of the hoof, using the dull side of a hoof knife. Turn the hoof knife to use the blade to lightly pare away any debris that obscures the surfaces of the frog, sulci of the frog, sole, and white line if the horse is unshod. Once the foot is clean, examine it in its entirety. The frog should be examined for size, shape, and consistency, and to determine whether it is securely attached to the underlying tissue and its sulci (collateral and central). The examiner needs to determine how much of the structure could actually bear weight and how much represents loose tissue. It is the author’s opinion that the frog should be a resilient, rubbery structure versus a hard, flaky consistency. The frog should be nearly even with the ground surface of the hoof wall, particularly the caudal two-thirds of the frog. The frog should not be recessed deep to the sulci of the foot nor should the frog be convex at its apex. The receded frog is often associated with upright narrow feet, whereas the convex frog is associated with weak and underrun heels. The author associates this conformation with a poorly constructed digital cushion and, therefore, a poor hoof-support mechanism.

The medial and lateral bars of the foot usually require light paring with a hoof knife to appreciate problems such as bar cracks. Do not pare the bars down totally, as this weakens the foot. The entire sole of the foot should be carefully examined for
fissures, punctures, consistency, discoloration (bruising), and the degree of concavity. The shape of the sole should be concave. If it is not, then the sole will be either flat or convex. A flat sole may signify either poor hoof conformation (a weak hoof) or coffin bone displacement. A convex sole, however, indicates a displaced coffin bone. The consistency (relative degree of stiffness) is usually determined using digital pressure as well as hoof testers. At this point, it is necessary to evaluate the texture of the sole. By grasping the quarters with your fingers, the thumbs can be used to gently press on the sole. If the sole moves under this pressure, it is thin and the examiner knows that there is little space between the coffin bone and the outside environment. On the other hand, if the sole does not move, the examiner knows there is at least some thickness and depth to the sole. The true sole depth can be determined later via radiography.

The white line is examined to determine its width and character. The white line is usually wider at the toe and gradually tapers to a thinner structure as it approaches the heels. It is best visualized following either light paring with the hoof knife or light rasping of the superficial portion of the foot. It is used to demarcate the insensitive hoof from the sensitive hoof for the purpose of driving horseshoe nails. Everything outside the white line is insensitive, everything inside is considered sensitive. Widening of this area represents stress and separation of the laminar hoof wall from coronary hoof wall. The deeper the separation goes, the more severe the injury. This separation can be seen anywhere on the solar surface and indicates a bending force on the wall that is pulling the wall away from the coffin bone. Most frequently, this separation is seen at the toe and is referred to as “seedy toe,” because it looks like small seeds could fit between the spaces created by the separation.

From the rear (palmar/plantar) of the hoof, examine the bulbs of the heels to determine their relative position to one another. The strength of this tissue is assessed manually by attempting to distract the two bulbs from one another in a vertical direction. Digitally explore the heel bulbs for the presence of swelling, heat, pain, or separation at the coronet. The central sulcus of the frog needs to be examined and probed to determine its depth. Normally, this should be a shallow depression of no more than a centimeter. If the sulcus goes deeper, there may be either very serious thrush or loss of structural support in heel bulbs, in which case the heel bulbs can be distracted in opposite vertical directions.

Lightly support the limb at the metacarpus (metatarsus) and allow the foot to drop naturally. Position your line of vision so as to appreciate foot balance and levelness of the walls. Imagine a line drawn through the axial center of the limb, which transects the ground surface of the foot, and then determine the relative proportion of medial and lateral foot to this imaginary line. For example, a given foot may demonstrate a unilateral medial heel contraction in combination with a flared lateral quarter and toe (diagonal imbalance).

Repeat the palpation of the cartilages of the distal phalanx and the coronet. Bringing the limb forward and flexing the toe facilitate palpation in the region of the extensor process of the distal phalanx and the associated distal interphalangeal joint. The thumbs or index fingers can then be pressed over this area to feel for joint distension, heat, or pain. The foot also should be rotated (twisted) medially and laterally around the vertical axis of the pastern. A normal range of motion allows for 10–15 degrees of rotation each way. Injury to the joint capsule, collateral ligaments, or chronic navicular pain tends to reduce this motion. Likewise, distal limb flexion should reveal 30–45 degrees of excursion. Again, injury to the joint capsule, collateral ligaments, or chronic navicular pain tends to reduce this motion.

If the horse is shod, the exam should include the following additions. First, determine the security of the shoe to the foot by gently rapping the shoe at one-inch intervals with a shoeing hammer. Make note of the shoe type as well as the presence or absence of additions, such as toe grabs, block heels, trailers, and so forth. Carefully determine if abnormal shoe wear exists. Position the hoof testers to include the hoof wall at the exit point of each nail. Carefully record your findings, as it is easy to forget subtle discoveries that may ultimately determine how the horse should be treated or shod. Keep in mind that hoof testers are essential but certainly not foolproof. The response the examiner gets on hoof testers is dependent on many factors, such as the hardness of the wall, depth of the hoof, thickness of the hoof, and the stoicism of the horse.

4. Objective Assessment

As part of any evaluation of the hoof, an objective assessment of hoof balance is important. Measurements are made of each forefoot. The horse's weight is determined with a weight tape or scale. Measurements are made of the hoof length with a tape measure (these can also be done using computer programs): medial and lateral heel lengths, vertical distance from the heel coronary band, and sagittal toe length. In addition, the frog's length and width are measured at their longest and widest points. The hoof angle is measured using a hoof gauge, and hoof circumference is measured immediately below the coronary band. These measurements are used to compare right to left but they can also be used to calculate the frog ratio (frog width divided by length), body size to hoof area (horse's weight [pounds] × 12.56/square of the hoof wall circumference [C] [inches]), and the heel measurements, with the vertical distance of the heel to the ground used to calculate the angle of the heels. These measurements can be used to identify measurable hoof imbalance. A lateral radiograph can
be used to more accurately assess this relationship. Underrun heels are defined as when the angle of the heels of the hoof is 5° less than the toe angle. Contracted heels have been defined as a ratio of the frog length to frog width. When the frog width is less than two-thirds the frog length, contracted heels exist. Sheared heels can be defined as any mediolateral asymmetry. Sheared heels, a form of mediolateral imbalance, have been defined as a mediolateral hoof wall length disparity of 0.5 cm or more. Mismatched hoof angles have been defined as a right to left hoof angle disparity of more than 2°. Weight to hoof size is calculated by multiplying the horse’s weight by 12.56, then dividing that by the square of the measured hoof circumference. The maximum hoof to weight ratio is 78 lbs/in² (5.5kg/cm²).

Previous studies have shown that these imbalances can affect future soundness. Broken-back hoof axis occurs in about 10% of athletic horses. However, it is three times more likely to be seen in a foot lame horse. Likewise, broken-forward axis occurs in 4% of normal horses but is two times more likely to be seen in a foot lame horse. Underrun heels are the most common hoof imbalance, occurring in 52% of non-lame athletic horses, but this imbalance occurs 1.5 times more often in lame horses. Contracted heels, measured as frog width less than two-thirds the length, have only been associated with 22% of non-lame horses, but it is 3.3 times more likely to be seen in a horse with foot lameness. Medial-lateral imbalance is seen in normal horses only about 12% of the time, but horses that develop foot lameness are 2.75 times more likely to have this imbalance. On the other hand, mismatched hoof angles occur in about 28% of horses and are equally likely to be present in lame horses as sound horses. Body weight to hoof area of greater than 78 lbs/in² occurs in only 2% of competitive horses. Horses that develop hoof lameness are 7.5 times more likely to have small feet for their body weight.

These measurements also impact prognosis for associated lameness. If a horse becomes lame and the hoof has underrun, contracted, and sheared heels, that horse is four times less likely to have the lameness successfully resolved. Another prognostic factor is weight to hoof area ratio. Horses with a ratio of greater than or equal to 83 lbs/in² are extremely unlikely to have the lameness resolved. This is a grave prognostic sign; the author has never successfully resolved a case with this hoof ratio.

5. Assessment of Pain

The next step in developing a logical approach to the evaluation of the hoof is an accurate exploration for pain in the foot and careful evaluation of hoof structure that may predispose to or cause the pain.

First, examine the horse in motion, watching the foot strike for each foot. Determine if the foot lands flat, heel or toe first, and medial or lateral quarter first. The landing position of the individual foot relative to the vertical axis of the respective foot should be noted. Evaluate the path the individual foot takes from foot breakover to strike. The character of motion may be a clue as to where on the foot or the limb a problem may exist. Always include this examination at the walk because it is the one gait that is sufficiently slow to permit the determination of fine movement error. Repeat the same process when reviewing the horse from the left and right side. The horse is then trotted (or paced) and visualized in the same manner. Circling the horse will often exacerbate foot problems.

Toe-first landing or excessive heel-first landing indicates either compensation for pain or dorsopalmar hoof imbalance. Similarly, medial or excessive lateral heel/quarter-first landing suggest either compensation for limb conformation or pain leading to mediolateral hoof imbalance. The flight of the foot during the stride is correlated with rotational deviation of the limb and imbalance of the foot. The horse that wings-in or “dishes” is either toed-out or breaking over the inside toe. Conversely, the horse that paddles or wings-out is either toed-in or breaking over the outside toe.

Diagnostic tests that should be performed are hoof tester examination, distal limb flexion, hoof extension wedge test, palmar hoof wedge test, and lateromedial wall wedge tests. Positive response to any of these tests is important, but a negative response is equivocal and does not rule out any problem.

Hoof tester examination should be performed systematically, how you perform the exam is unimportant but get use to a routine. The author likes to begin at the heel on his left side and work around the hoof in a clockwise fashion. Begin with the bar, move to the heel, to quarter, and then toe, then back toward the heel on your right. Space the tester’s progress at approximately one-inch intervals. Be sure to include each exit point of the shoeing nails. Next, place the testers in each of the collateral sulci and across the hoof to the opposite hoof wall (the author likes to progressively move the hoof tester along the hoof wall caudal to cranial to check for alterations in the pain response, then place the testers in the central sulcus to the hoof wall at the toe, and then across the heels). Remember that the closer the ends of the hoof testers are, the more accurate the exam is in localizing pain. A positive response should be repeatable, and in the frog region, the pain response should be uniform over those areas and must be evaluated in relation to examination of the remaining foot. That is, a positive response in the heels and quarters of the sole would also be expected to cause a positive response across the distal sesamoidean region in the same area of the foot. Percussion using a small hammer can also provide important information regarding pain in the hoof wall or sole by gently rapping the structures on the bearing surface of the sole and frog and over the hoof capsule.
A distal limb flexion test may exacerbate lameness if any of the three distal joints of the leg are affected by synovitis or osteoarthritis. A positive response could also be expected by any condition that causes induration of the tissues of the foot. A distal limb flexion test is performed by flexing the distal limb, holding the limb in that position, and trotting the horse away after 30 seconds. This has been shown to be positive in over 95% of horses with foot pain.

The hoof extension test is performed by elevating the toe with a block, holding up the opposite limb, and trotting the horse away after 60 seconds. This test has a positive predictive value for foot pain of about 50%. The palmar hoof wedge test is performed in a similar fashion, except the block is placed under the palmar two-thirds of the frog, forcing the horse to stand on that foot. The test can be further modified so that the wedge can be placed under either heel to determine if the pressure there causes exacerbation of the lameness. This test has a positive predictive value for foot pain of over 85%. Finally, the wedge can be placed under the medial and lateral wall to stress the coffin joint collateral ligaments and joint capsule. The author has found this to be a very reliable test for pain in the collateral ligaments.

These tests simply allow the examiner to evaluate the horse’s response to a particular stress and have not been shown to be pathognomonic for any particular lameness. Regional analgesia will provide the evidence to localize the region of pain. Regional analgesia needs to be performed in a logical manner. Intra-articular injections anesthetize joint regions, whereas regional analgesia desensitizes skin segments. Intra-articular injection is more accurate and does not interfere with regional analgesia. Regional anesthesia desensitizes local nerves that innervate areas of the limb. They provide indisputable evidence of the location of lameness. The most important point is to have some idea of what areas have been desensitized. This is most often accomplished by pin-prick after the procedure.

Clipping is usually not necessary. A surgical scrub of the area is a must. The author likes to apply a pressure bandage at the end of the exam to decrease swelling, because local anesthetics are irritating and can cause the leg to swell. For most peripheral nerve blocks, a 22–25-gauge 5/8–1.5-inch needle is used. Lidocaine (xylocaine) and mepivacaine (carbocaine) are the most popular anesthetic solution.

The palmar digital nerve block is frequently performed midway between the fetlock and coronary band. The author prefers to perform this block at the level of the collateral cartilages. The neurovascular structures can be palpated in a groove between the pastern bones and flexor tendons, and 1.5–2 ml of anesthetic are injected over the nerve. This desensitizes the caudal 1/3–1/2 of the skin at the coronary band, plus the heels and quarters of the hoof wall, as well as the entire sole. The effects of regional analgesia are usually evaluated 15 minutes after injection.

The pastern ring block is a simple extension of the palmar digital nerve block. Simply inject anesthetic around the dorsal surface of the pastern from nerve to nerve. This anesthetizes the entire hoof and pastern from the block distally. The abaxial sesamoid nerve block is performed on the palmar aspect of the abaxial surface of the proximal sesamoids. The neurovascular structures are very easily palpated and 1.5–2 ml of anesthetic are injected over the nerve. This should make a small bleb that is easily seen. The abaxial block desensitizes the hoof capsule and the caudal pastern.

Joint blocks provide evidence of specific joint involvement. Typically, the author does not clip the hair as long as the horse has a short haircoat. A surgical scrub of the area is an absolute must. Always be sterile (e.g., needles, anesthetic solution, and syringes). The supplies that you will need are 20–23-gauge 1–1.5-inch needles. Lidocaine and mepivacaine are most commonly used.

For the distal interphalangeal (DIP) joint (coffin joint), there are two good techniques. Regardless of the technique, it is frequently questioned as to what is desensitized by a DIP block. It is the author’s opinion that the DIP block desensitizes the DIP joint, the navicular bone, and the innervated portions of the navicular bursa.

Schumacher showed that the interpretation of diagnostic analgesia into the DIP joint must be done carefully. He performed an experiment where he induced lameness by forcing setscrews into the sole of a horse’s foot. The subsequent lameness was alleviated by DIP analgesia. This led the authors to conclude that local anesthetic into the DIP joint could alleviate pain in the sole. This information was contradictory to what this author had observed. In a separate experiment, the author used a Dremel tool to expose sensitive sole on horses’ feet. The exposure was adequate so that “pin pricking” of the exposed area would cause pain. The author then injected the DIP with anesthetic and noted the sole remained sensitive. On the other hand, when the palmar digital nerve was anesthetized, the sole was desensitized. One other observation was that the sole was not as sensitive as the author thought it would be. This observation led the author to believe that the setscrews model creates lameness by causing the horse to land abnormally away from the pressure but that the pain the horse perceives as a result of this is via the DIP joint.

The proximal interphalangeal joint (pastern) can be injected either through the dorsal or palmar pouches. At this time, most everyone agrees that injection of the pastern only desensitizes the pastern joint.

Podotrochlear bursa analgesia can be performed either from the palmar (plantar) aspect or from the lateral aspect. Regardless, some type of radiographic control is needed to insure the bursa has...
been injected. The lameness is evaluated 5 to 10 minutes after injection. It is thought that this injection desensitizes the navicular bone and its ligaments plus the entire solar aspect of the third phalanx, including the insertional area of the deep flexor tendon.8

6. Conclusion

The examination of the foot must be based on observations of the hoof, followed by a careful exploration for areas of pain. This must be followed by an assessment of the biomechanical forces on the hoof and limb. Finally, imaging gives insight into the nature of the stresses on the foot and allows the examiner to assess the prognosis for its athletic future.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

How to Manage Club Feet in Adolescent Horses

Craig S. Lesser, DVM, CF

1. Introduction
There are a wide range of commonly encountered hoof and conformational deformities that can be therapeutically treated in foals to prevent the need for lifelong therapeutic shoeing and the risk of limiting their athletic abilities. One commonly observed condition is that of the club foot. Club feet can develop at a variety of ages from as young as a few weeks of age to a mature horse and can be congenital or acquired. There are often multiple factors leading toward a horse’s development of a club foot conformation, and much is still unknown. However, as we continue to learn, we are getting better at treating and preventing this condition. When horses are young, we are able to manipulate the hoof capsule and, at times, the underlying bone structure to create a more conformationally correct foot.

2. Methods and Materials

Identification and Grading
Identification of a club foot early in its formation and knowing how to respond to these changes are essential for treatment. Proper evaluation of these foals should be done by walking the foal away from and toward you in a straight line, along with evaluations from both sides to identify minor conformational differences. The four grade system, described by Dr. Ric Redden, gives quality descriptors of the severity of a club foot, with grade one being the lowest grade and grade four being the most severely affected.

- Grade one is classified by having a hoof angle that is at least five degrees greater than that of the contralateral hoof. The hoof will show no deformation in the dorsal hoof wall; however, the heels will be contracted, and the frog will be smaller than the contralateral hoof. The growth rings will be relatively parallel.
- Grade two is classified by having divergent growth rings at the heel compared to that at the toe. The dorsal wall will be about 10 degrees steeper than the contralateral limb, and signs of excessive wear at the toe may be evident.
- Grade three is classified by a foot with a dished dorsal wall and deviation of the growth rings so that they are twice as wide at the heel as they are at the toe.
- Grade four is classified by a foot with a heavily dished dorsal hoof wall. The coronary band is parallel to the ground due to the rapid growth of heel and impingement of growth at the toe.

There is a great deal of speculation as to the etiology of club feet; however, it is likely to have multiple causes, including in utero contracture, inflamma-
tion, genetic, limb length disparity, and grazing patterns.

Newborns
Foals born with coffin or fetlock joint contracture often result with a club foot formation. This is due to the contraction of the deep digital flexor tendon (DDFT) and check ligament. It is important to evaluate for this conformational defect on initial examination and pursue correction of all contractions. When foals are young, these structures are comprised of a large proportion of myofibroblasts. This cellular structure allows for the use of tetracycline for relaxation. However, this can be contraindicated when some legs are contracted while others may already be too lax. Additionally, foals that were not splinted appropriately to resolve contracture often develop a club foot later in life. Therefore, other methods have been pursued to solve this problem.

In foals with minor contractions, a tight standing wrap is often enough to allow relaxation of the musculotendinous unit. These wraps should extend from below the coronary band to the base of the tarsus or carpus. This wrap should be reapplied daily until the foal is at an acceptable coffin joint and fetlock angle. In more difficult cases, or ones that have not immediately responded to bandaging alone, moldable splinting material should be added to the bandage to correct this deformity (Fig. 1). These splints are placed under sedation to allow for maximal relaxation of the foal. The splinting material is placed on top of the bandage from halfway up the dorsal wall extending up the palmar/plantar surface of the leg to just below the carpus/tarsus. This is then secured with elasticon, and pressure is placed dorsally to extend the leg until the splinting material has hardened. This method has been extremely rapid and efficacious and has greatly reduced the author’s use of oxytetracycline to relax foals.

Trimming
Trimming foals every three weeks beginning as early as one day of age, if needed, can correct a wide range of deformities. A large proportion of club-footed horses, especially the grade one and a portion of the grade twos, can be corrected with trimming alone. The use of a full rocker trim (Fig. 2) allows for the development of a healthy hoof capsule while positively influencing internal structures. This trim involves rockering the heels down to the highest and widest part of the frog. This will make the hoof optically pleasing, as it will widen the hoof by opening up the heels and engaging the frog, and it will also bring the dorsal hoof wall angle back toward a similar angle with the other hoof. Internally this will put increased tension on the DDFT. This force will stretch the tendon to allow for its length to match. It should be noted that this requires a delicate balance of increased tension without overload of the tendon, which could lead to worsening of a club foot. To alleviate excess influence of the DDFT on the hoof capsule, the toe of the hoof is rockered, creating the full rocker trim. This allows for the increased tension of the DDFT at the stance phase while in motion there is not an excessive load on the DDFT from the additional toe leverage.
This trim technique forces the foal to breakover square, and together with a combination of other trimming techniques, additional conformational deformities can thus be influenced.

Shoeing
If the trim results in the heels of the hoof to no longer be touching the ground, a shoe will need to be applied to compensate for the contracture of the DDFT and allow it to be slowly stretched. The use of a wedged, roller motion, polyurethane shoe with sole support can be effective (Fig. 3). This shoe is flexible enough to allow the growing hoof to continue to expand, yet it gives the mechanics necessary to allow the DDFT to relax and the hoof capsule to return to normal. A good relationship between the veterinarian and the farrier is important, as the foal will need to be sedated to ensure it is cooperative as the shoe is glued on.

Gluing on these shoes is a daunting process initially; however, after a few times their application becomes easy. The process begins by trimming the foot in a fashion to have as normal looking of a hoof capsule as possible. Heels should be lowered to the highest and widest point of the frog, and distortions, such as flaring at the toe, should be removed. The foot is then sanded to remove excess oil and debris from the surface of the foot, and the roughening of the hoof allows for increased surface area for attachment of the glue. The sole should be lightly torched to remove excess bacteria and moisture, and the commissures should be cleaned. If there are any separations, they should be packed with an antiseptic agent to prevent abscessation.

The shoe should be shaped to the foot to place the hoof directly under the limb. Adequate expansion and length of the shoe extending back to the origin of growth is necessary to allow the hoof to continue to grow. Setting the toe of the shoe just slightly ahead of the foal's toe will provide protection to the toe area along with a slight amount of tension. True toe extensions force the heels to be on the ground, which often causes more damage to the hoof than help, so excessive leverage in front of the toe should be avoided.

The shoe is applied using glue to form a seamless transition from hoof through shoe making sure to not have glue on the wall of the hoof and no glue on the sole (besides under the shoe). These shoes lock onto the hoof via the heels, and it is very important to have clean commissures to avoid pinching of the heels. A mesh can be stapled onto the sole surface of the shoe to allow for an attachment surface for the equathane pad. This will engage the frog and encourage expansion of the hoof capsule. This shoe can be left on for 3–6 weeks depending on the severity of the club foot, rate of growth of the foot, and the security of the shoe. If progress is being made, multiple shoeings may be necessary.

Spring Shoe
If the hoof is contracted in addition to upright, a spring shoe can be used to widen the hoof and open up the heels. This can be done using either a polyurethane shoe with a spring or a hinge shoe with a spring (Fig. 4). The mechanical concept behind a spring is to put constant abaxial pressure on the heels, thus expanding the heels over the course of the shoeing cycle. These shoes will be shaped to the foot, then a wire will be placed near the heels to hold the shape of the shoe. The spring can then be placed in the shoe, and the shoe can be applied in a similar fashion as described above. After the glue has been cured, the spring can be released by cutting and removing the wires that were placed to hold the shoe in the shape. Many of these feet will noticeably open immediately after release of the spring.

In more complicated cases, these techniques can be applied in combination. Many of the higher graded club-footed horses have contracted heels and a deviation in the growth rings. In these cases, a
wedged hinge spring shoe can be used for maximal effect. Changes in shape and size of the coffin bone have been described after application of these shoes.

Distal Check Ligament Desmotomy
Surgical intervention is pursued if shoeing changes have not achieved the desired results or there are radiographic signs of bony changes. This procedure is extremely effective especially in severe cases, before there are significant bony changes. Contraindications of this procedure are the possibility of white hairs or other blemishes at the incision site. Additionally, undercorrection is common with this procedure if trimming and shoeing techniques are not performed correctly.

Post-surgery, the hoof should be trimmed so that the heels are as low as possible and the toe is left for leverage and protection. A low field hoof radiograph should be taken to determine the palmar angle of the coffin bone. The goal is to have the palmar angle of the coffin bone parallel to the ground surface and the heels touching the ground. If the heels are not staying on the ground after this procedure or a zero palmar angle is not achieved, shoeing should be pursued.

Foals that do not keep their heels on the ground will need to have a toe extension (Fig. 5). The use of an aluminum race plate with a broad toe extension is often very effective. The length of the toe extension should be determined based on the conformation of the foal. A line drawn from the coronary band to the floor, parallel to the pastern, will give you the proper placement of the toe extension (Fig. 6). This angle is the desired angle of the hoof wall that will provide a direction of growth for the new hoof. These toe extension shoes can be prepared and applied in the same manner as the previously described above.

If a zero palmar angle was not able to be achieved in the trim, a reverse wedge toe extension should be considered. The angle of the toe wedge should be equal to the palmar angle of the coffin bone post trim, thus bringing the palmar angle to zero post shoeing. A direct glue shoe is often difficult to keep on these foals due to the forces placed on the shoe. Instead, an indirectly glued-on shoe with the proper mechanics can be considered. These shoes have a cuff that will be glued onto the hoof wall, staying below the coronary band.

These horses should be re-evaluated with radiographs in 3–6 weeks. If enough sole has grown to allow the hoof to be trimmed and left barefoot, that is ideal; otherwise, additional shoeing may be necessary.

3. Results
Over the past year, this splinting technique has been the primary form of splinting foals in the author’s practice. Foals with contracture typically resolve with 2–3 days of splint application, but up to five days may be necessary in extremely contracted cases. Unfortunately, exact numbers of DDFT and superficial digital flexor tendon contractures are unknown, as they are combined in records.

The number of mild club-footed foals trimmed annually is difficult to track, as many are trimmed with a rocker trim as part of a quality trim and not noted due to the common nature of the deformation. The polyurethane shoes are also difficult to track, as they are applied for a variety of reasons beyond club feet.

Approximately 375 spring shoes are applied to foals and yearlings annually. Results are favorable; however, in extremely contracted cases, multiple applications of spring shoes and occasionally multiple springs are necessary to exert enough abaxial force on the capsule.

Due to the Thoroughbred population of the author’s practice demographic, not many check ligament desmotomies are performed. Farm managers are often concerned with the possibility of blemishes that would decrease sale value. Therefore, this procedure is often not pursued until cases have reached grade four or the coffin bone starts to remodel. The author has not come across overcorrec-
tion as an issue, as many of the severe cases still exhibit signs of a club foot once bony changes have occurred.

In the author’s practice, there is an estimate of 1–3 foals that have club feet that are grade two or higher. This number varies some annually depending on which stallions are popular each year. Some stallions and breeds have a reputation for passing along club foot conformation.

4. Discussion

There is a great deal of knowledge lacking in the field of podiatry, and most of the research is based in anecdotes rather than quality science. Due to the nature of the author’s practice, many of these cases are lost to follow-up once the veterinarian or farm manager has deemed the conformational fault corrected. The portion that are followed through yearling sales continue to grow normally with maintenance trimming and correction.

Proper hoof care is essential for horses to succeed in their intended discipline, and knowing how to assess and manipulate abnormalities in young horses is important to prevent lifelong complications.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Equine Hoof Capsule Distortions: An Overview

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1. Introduction
The hoof capsule is comprised of the hoof wall, sole, frog, and bulbs of the heels, which, through the unique continuous bond between its components, form a casing on the ground surface of the limb that affords protection to the soft tissue and osseous structures enclosed within the capsule. The hoof wall is a viscoelastic structure that has the ability to deform under load and then return to its original shape when the weight is removed. It is well accepted that abnormal weight distribution on the foot or disproportionate forces placed on a section of the hoof will, over time, cause it to assume an abnormal shape. These abnormal stresses within the foot will also predispose the foot to injury or disease. Increased stress or weight bearing placed on a section of the hoof capsule can manifest itself in a variety of ways, such as compressed growth rings, flares or under running of the hoof wall, dorsal migration of the heels, and either focal or diffuse displacement of the coronary band. Distortion of the hoof capsule of the forelimbs appears to be related to limb alignment and load, whereas deformation in the hind feet seems to be different and related to propulsion. As the hoof capsule distortion of the forelimbs is commonly associated with lameness and various disease processes, only the forelimbs will be considered in this paper. As the “normal” foot has never been defined, an attempt will be made to describe what the author perceives to be an ideal, good, or healthy foot. Palpation of the hoof capsule often complements the visual examination and the areas where palpation is relevant will be included. Any evaluation of the hoof capsule seeks to identify deformation and changes in the growth pattern, which indicate abnormal distribution of forces (stresses) on the foot. The most common hoof capsule distortions encountered in equine veterinary practice are the long toe-low heel conformation, clubfoot, sheared heels, and mismatched feet. As hoof capsule distortion and abnormal loading usually accompany lameness, farriery will form part of or sometimes the entire treatment.

2. Mechanism of Distortion
The hoof capsule morphology will indicate where the hoof wall is unduly stressed; however, the clinical evaluation has to be coupled with an understanding of the abnormal distribution of forces that lead to hoof capsule deformation. Increased load or weight bearing on a portion of the hoof wall has three consequences: (1) it may cause deviation of the wall...
The center of pressure (COP) is the point on the ground that opposes the weight with an equal and opposite force. A line dropped from the metacarpophalangeal joint to the ground should bisect the hoof capsule, leading to deformation. In the frontal plane, the forelimbs should be of equal length and size and bear equal weight. A line dropped from the scapulohumeral joint to the ground should bisect the limb. Certain types of abnormal limb conformation have been described. In the frontal plane, abnormal conformation is described as valgus (the limb's segment distal to the affected joint will deviate laterally) or varus (the distal segment of the limb will deviate medially). The joint most often affected is the carpus and, to a lesser degree, the metacarpophalangeal joint. Here, there will be excess load placed on the hoof opposite the direction of the deviation. If a line dropped from the metacarpophalangeal joint through the digit to the ground does not bisect the hoof capsule, the foot is considered offset to one side (usually laterally) and, therefore, increased load is placed on the opposite side of the foot (Fig. 2). In the transverse plane, conformation abnormalities are characterized by axial rotations of the limb or its segments, either laterally or medially. For example, a horse with a narrow chest and a lateral axial rotation will land on the lateral side of the hoof and then load the medial side, resulting in proximal displacement of the quarter/heel on the medial side and causing the hoof deformation termed sheared heels (Fig. 3). A limb with a medial (inward) rotation of the digit relative to the third metacarpal bone (toed-in) may develop a hoof with a diagonal asymmetry, with a narrow lateral toe and medial heel and a wide medial toe and lateral heel. The altered distribution of forces leading to hoof capsule deformations follow a logical pattern where the overloaded sections of the hoof are less developed and the under-loaded sections are overdeveloped. In the sagittal plane, abnormal

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\textbf{3. Limb Conformation}

When evaluating hoof capsule deformation, limb conformation should be considered. Abnormal limb conformation affects the landing pattern and stance phase of the stride. Few horses have ideal limb conformation and any change in conformation may lead to a change in the distribution of forces within the hoof capsule, leading to deformation. In the frontal plane, abnormal conformation is described as valgus (the limb's segment distal to the affected joint will deviate laterally) or varus (the distal segment of the limb will deviate medially). The joint most often affected is the carpus and, to a lesser degree, the metacarpophalangeal joint. Here, there will be excess load placed on the hoof opposite the direction of the deviation. If a line dropped from the metacarpophalangeal joint through the digit to the ground does not bisect the hoof capsule, the foot is considered offset to one side (usually laterally) and, therefore, increased load is placed on the opposite side of the foot (Fig. 2). In the transverse plane, conformation abnormalities are characterized by axial rotations of the limb or its segments, either laterally or medially. For example, a horse with a narrow chest and a lateral axial rotation will land on the lateral side of the hoof and then load the medial side, resulting in proximal displacement of the quarter/heel on the medial side and causing the hoof deformation termed sheared heels (Fig. 3). A limb with a medial (inward) rotation of the digit relative to the third metacarpal bone (toed-in) may develop a hoof with a diagonal asymmetry, with a narrow lateral toe and medial heel and a wide medial toe and lateral heel. The altered distribution of forces leading to hoof capsule deformations follow a logical pattern where the overloaded sections of the hoof are less developed and the under-loaded sections are overdeveloped. In the sagittal plane, abnormal}
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conformation can best be described by the position of the DIP joint, either a flexural deformity or marked dorsiflexion (i.e., extension) of the joint. The shape or conformation of the hoof in the sagittal plane will be dependent on the tension in the DDFT, the integrity of the laminar apparatus, and the digital cushion, all of which determine the angle of the solar margin of the distal phalanx. A flexural deformity will overload the toe, whereas marked dorsiflexion of the DIP joint will overload the palmar section of the foot.

4. **Healthy Foot**

A morphological description of what is considered to be a good or ideal foot can be used as a model not only to relate or compare a hoof capsule distortion but also as a template or guideline when formulating a farriery plan. Examination of the foot begins with the horse standing square on a firm, flat surface and the foot viewed from all sides. Following visual examination of the feet, the horse should be observed in motion, both going away from and toward the examiner, on a firm flat surface to note the landing pattern of the foot as it strikes the ground. Finally, the ground surface is examined with the foot off the ground. Additionally, small changes in the shape of the hoof capsule (such as the coronet and the digital cushion) may be further appreciated by careful palpation of the foot than by visual inspection.

**Dorsal Aspect**

When the foot is viewed from the dorsal aspect, the ideal hoof should be approximately symmetrical. An imaginary line drawn between any two comparable points on the coronary band should be parallel to the ground. The medial wall should be the same height as the lateral wall, but because it is often slightly steeper, it may be slightly shorter. An imaginary line that bisects the third metacarpal should bisect a line drawn between any two comparable points on the coronary band or the ground surface of the hoof. Similarly, the hoof should be symmetrically related to the distal limb such that an imaginary line that bisects the third metacarpal bone bisects the pastern and the hoof, allowing for the slight asymmetry due to the different angles of the medial and lateral wall (Fig. 4A). When the foot is viewed from the dorsal aspect, the shape of the forefeet may be asymmetrical, with one hoof being narrower than the other (“mismatched feet”).

On palpation, the coronary band of a healthy hoof should feel thick and spongy. There should be no evidence of a “ledge” or “trough” behind the proximal margin of the hoof capsule when palpated. A depression in the coronary band indicates that the distal phalanx has displaced within the hoof capsule, a finding that can be present in sound horses. This palpable depression will generally be accompanied by a thin, flat sole, narrow frog, and contracted heels. The dorsal aspect of the coronary band should also be palpated for effusion of the DIP joint. This is often seen with horses that have a broken back hoof pastern axis (HPA) and synovitis of the DIP joint.

**Lateral Aspect**

When viewed from the lateral aspect, the angle the dorsal hoof wall forms with the ground is variable and typically related to the conformation of the digit. The heel tubules of the hoof capsule should form an angle with the weight-bearing surface similar to the angle of the horn tubules in the toe region. Tradition has it that the angle of the wall at the heel should match that of the dorsal hoof wall at the toe; however, it varies and is generally a few degrees
less. The length of the dorsal hoof wall is similarly variable, but is determined by the amount of sole depth present. There are two guidelines that relate the proportion of the foot to the rest of the distal limb. First, the foot pastern axis describes the relationship between the angles made by the dorsal hoof wall and the dorsal aspect of the pastern with the ground. Ideally, the dorsal hoof wall and the pastern form the same angle with the ground so that the angle between them is 180° and the axis is considered straight. Second, an imaginary line that bisects the third metacarpal bone should intersect the ground at the palmar aspect of the heels of the hoof capsule (Fig. 4B). The healthy coronary band should have a gentle, even slope from the toe to the heels and the hair should lie flat against the hoof capsule; hair projecting horizontally may indicate excessive forces on the associated hoof wall.1 The width of the growth rings below the coronet should be equal from toe to heel. A disparity in the width of the growth rings between the toe and the heels is indicative of nonuniform circulation of the coronary corium or excessive forces below, because wall growth is generally inversely related to load at the bearing border of the foot.

Palmar Aspect

The heels are evaluated from the palmar aspect for their overall width and height. The heels frequently become narrower when the foot itself is narrow. The overall height of the heels is readily assessed from the lateral aspect but viewing from the palmar aspect is useful to compare the relative heights of the two heels when measuring from the hairline at the bulbs to the ground. For example, in the case of the sheared heel, one heel is displaced proximally relative to the other heel. Another example is mismatched feet where there is a marked disparity in heel height between feet. The contour of the junction of the heel bulbs with the skin can be evaluated relative to the width of the hoof wall at the heels and the thickness of the digital cushion (Fig. 4C).

Distal or Solar Aspect

When viewed from the distal surface, the ground surface of the foot should be approximately as wide as it is long.1,2 The foot should be approximately symmetrical about the long axis of the frog; the lateral side of the sole frequently has a slightly greater surface area that corresponds with the difference in wall angles at the quarters described in the dorsal view. The width of the frog should be approximately 60–70% of its length.14 The ground surface of the heels should not project dorsal to the base of the frog, and the hoof wall at the heels and the frog should be on the same horizontal plane. Imaginary lines drawn across the most palmar weight-bearing surface of the heels and across the heel bulbs at the coronary band should be parallel and both lines should be perpendicular to the axis of the frog (Fig. 4D).1

The author further evaluates the solar surface of the hoof capsule by drawing a line across the widest part of the foot. This line forms a consistent landmark and is located just dorsal to the COR (of the DIP joint). Using this line as a starting point, there should be approximate proportions from this line to the perimeter of the toe and to the base of the frog. Hoof balance or a balanced foot has been used historically to describe the ideal hoof conformation. However, hoof balance has no consistent definition and remains a concept. The author prefers to use the term “proportional foot” to describe an acceptable foot conformation. This term can be used to
access foot conformation from the lateral side as well as the ground surface of the foot by using the COR as the intersection between the proportions (Figs. 5A and 5B).

5. Long-Toe, Low-Heel Foot Conformation

A low-heel conformation can readily occur with or without excessive toe length. This type of foot configuration is so common in equine practice, especially in Thoroughbred horses, that it is thought to be normal. A long-toe/low or underrun heel conformation (LT-LH) is defined as the angle of the heels being considerably less than the angle of the dorsal hoof wall. When this difference in angles is considerable, it is characterized by a broken back HPA where the angle of the dorsal hoof wall is lower than the angle of the dorsal pastern. It is often the result of leaving the heels to migrate dorsally when trimming, which allows them to grow forward and lose their angle. When evaluating the foot from the lateral aspect, there will be disproportionate distances on either side of the middle of the foot to the toe and to the heel. There may or may not be a flare in the dorsal hoof wall. The coronet will reveal an acute angle from the toe to the heel and the coronet at the heels will thicken and begin to form a “knob” shaped appearance. The angulation of the horn tubules will decrease from toe to heel and may often be parallel with the ground at the heel (Fig. 6). The ground surface of the foot will again show a disproportionate distance from the widest part of the foot to the perimeter of the toe and to the base of the frog. The heels of the hoof capsule will have migrated dorsally while the soft tissue structures are located palmar to the end of the heels, and, in many cases, the frog is situated distal to the bearing border of the hoof wall. Interestingly, when observed in motion on a firm flat surface, a horse with LT-LH conformation may have a markedly heel-first landing due to the lack of ground surface in the palmar foot, the horse may land flat, or the horse may land toe first if they are experiencing discomfort in the palmar foot.

A low hoof angle results in dorsiflexion of the DIP joint, which concentrates weight bearing on the palmar section of the foot and increases strain on the DDFT. This excess load, in turn, may cause increased stresses on the navicular apparatus and the soft tissue structures associated with the palmar foot and the joints proximally (Figs. 7A and 7B).

If low or underrun heels are allowed to progress, this condition can be readily observed both visually and radiographically; the point at which the angle that the hoof capsule or the distal phalanx forms with the ground is lower palmarly/plantarly than it is dorsally. A negative angle of the solar border of the distal phalanx, as noted radiographically, means that the soft tissue structures (frog, digital cushion) are underdeveloped or have decreased in mass, usually due to damage, or they have prolapsed palmarly which allows the distal phalanx to descend distally (Fig. 8). Biomechanically, it changes the angle of insertion of the DDFT on the distal phalanx, increases the peak force on the navicular bone bursa, and moves the GRF dorsally toward the toe (Fig. 9).

Farriery

The treatment of low or underrun heels is difficult, and often the conformation of the heels can only be maintained rather than improved. Farriery seeks to reduce the length of the dorsal wall and redistribute the weight on the ground surface of the foot. The traditional farriery for low or underrun heels is to use an egg bar shoe to support the heels, often accompanied by some form of heel elevation to raise the angle of the heels and correct the broken back HPA. However, it is questionable whether “support” can be applied to compromised structures (heels) that no longer have the ability to accept weight, and the egg bar shoe may do little more that apply leverage to the palmar foot.

The ability to improve the soft tissue structures in the palmar foot and to produce new hoof wall growth at the heels may be limited. In the author’s experience,
it appears that some form of structural framework is necessary to support renewed hoof wall growth at the heels. In the palmar foot, this “framework” seems to be the digital cushion, frog apparatus, and ungual cartilages, and when these structures are compromised, renewed hoof wall growth is poor or absent. Various techniques have been successful, depending on the amount and integrity of the structures present. When possible, the author has had success leaving the shoes off and allowing the horse to be barefoot for 30–60 days. This method is useful if the frog is located distal to the ground surface of the foot, as it will put the frog back on the same plane with the hoof wall. Otherwise, when a prolapsed frog is present, the shoe should be removed, excess horn trimmed from the frog, and the horse stood on a hard surface such as a rubber stall mat for 24–48 hours before the trim.

Foot preparation begins in all feet by visualizing the two basic landmarks on the ground surface of the foot: the widest part of the foot and the base of the frog. The palmar section of the foot is trimmed appropriately by using the widest part of the foot as a starting point, and the heels are trimmed to healthy horn when possible, making sure that all of the structures of the heel and the frog are on the same plane. The toe is shortened accordingly, again using the widest part of the foot as a guideline. Many horses with a LT-LH will have decreased sole depth, so, when necessary, the toe length can be reduced by using the nippers in a vertical plane across the toe (which preserves sole depth) rather than using them in the usual horizontal plane. Following the trim, the heels are assessed with regard to the structural integrity and the structural mass present.

A shoe that attempts to place the load over the entire palmar foot complements the trim, not just on the hoof capsule at the heels (load sharing concept) and provides heel elevation to improve the HPA when possible. If the structures of the heel are intact and the hoof wall angle simply needs to be raised, an open aluminum wedge shoe or an open shoe can be used.

Fig. 7. A, Shows the increased pressure on the navicular bursa with a low heel combined with a negative angle of the solar border of the distal phalanx (Courtesy Dr. Andrew Parks). B, Shows the effects of a LT-LH on the DIP joint (Courtesy Renate Weller).

Fig. 8. Radiograph shows a negative angle of the solar border of the distal phalanx. Also note the alignment of the bones of the digit, the lack of structural mass in the palmar foot allowing the DP to descend, and the “knob”-shaped appearance of the soft tissue structures.

Fig. 9. The descent of the distal phalanx changes the angle of insertion of the DDFT on the DP and increases the tension in the DDFT. This increase in tension in the DDFT increases the flexor moment, which in turn increases the force of the extending moment moving the GRF dorsally toward the toe (Courtesy Dr. Andrew Parks).
steel or aluminum flat shoe with a wedge pad can be used to achieve the desired heel angle. Depending on the severity that the heels are damaged or compromised, a load-sharing effect can be accomplished by using a straight-bar shoe with a pad or degree pad placed between the shoe and the foot. The author is reluctant to use a heart-bar shoe if the frog and digital cushion lack sufficient structural mass. An open-steel or aluminum shoe with a heel plate welded between the branches of the shoe or a plastic bar wedge placed between the shoe and the foot can also be used. Holes can be drilled in the heel plate or bar wedge and some form of silastic material placed underneath the plate or wedge to create a deformable interface to spread the weight-bearing function over all the structures in the palmar foot. The same effect can be achieved by placing a “spider” plate between the shoe and the foot. Impression material is placed on the ground surface of the palmar foot, starting in the middle of the frog and extending palmarly as far as desired. The shoe and pad or plate are placed on the foot, and the heel of the shoe is pressed into the impression material, forming a slight wedge. Two nails are placed in the toe of the shoe and the foot is held off the ground until the impression material cures (Figs. 10A and 10B). Glue-on technology may be helpful to improve the structures in the heel but should not be applied long-term because damage to the hoof wall is thought to occur from the heat generated by the composite, and they have been shown to decrease expansion at the heels.18

Farriery for low heel conformation is often based on trial and error and combinations of various methods but depends on assessing the structures present, the footing, the athletic pursuit of the horse, and client expectations. Any form of farriery for LT-LH should be accompanied by enhancing breakover. Moving breakover palmarly can be accomplished in a variety of ways, such as rolling or rockering the toe of the shoe or creating a rolled toe in the shoe by using a hand grinder where the breakover begins at the inner branch of the shoe. Moving breakover palmarly/plantarly decreases the moment applied to the DIP joint and appears to decrease the maximum tension in the DDFT, which occurs toward the end of the stance phase at the beginning of breakover (Fig. 11).1–7

6. Upright or Clubfoot Conformation

Flexural deformities have been reported as a cause of decreased athletic performance and chronic low-grade lameness in the mature horse.19–22 A clubfoot is defined as an upright conformation of the foot associated with a flexural deformity of the DIP joint.19,21 It is characterized by a broken forward HPA, which is a reflection of a hoof capsule where the angle of the dorsal hoof wall is higher than the angle of the dorsal pastern. This broken forward HPA or flexural deformity is created by some degree of shortening of the musculotendinous unit (DDFT and associated muscle bellies), causing the DIP joint to be drawn into a flexed position. Biomechanically, as the tension in the DDFT increases, the COP moves dorsally in the toe (Figs. 12A–C).19,22

Examination from the lateral side generally reveals a broken forward HPA, the coronet assumes a more horizontal position, poor hoof wall consistency, a disparity of hoof wall growth with more growth at the heel than at the toe is generally present, and there will be some degree of a flare in the dorsal hoof wall. Looking at the ground surface of the foot, there will be disproportionate ground surface on either side of the widest part of the foot, with the palmar section showing less surface area, a thin
sole, separations at the toe, and the frog generally receding due to excess hoof wall growth at the heels. Observing the horse in motion, depending on the severity of the flexural deformity, the horse will either have a toe first landing pattern or will land flat.

**Farriery**

High hoof angles with no or mild phalangeal misalignment can generally be improved by gradually trimming the heels in a tapered fashion from the apex of the frog palmarly to the heels. The solar surface of the foot dorsal to the frog should not be trimmed so all sole thickness is maintained. This increases the ground surface of the foot and attempts to reestablish weight bearing on the entire solar surface of the foot. The upright foot will often have a thin sole, so toe length is reduced accordingly from the outer dorsal hoof wall with an attempt to remove any concavity in the wall. A flat-steel or aluminum shoe fitted so it extends beyond the heels of the hoof capsule and breakover moved palmarly to the first nail hole to compensate for any increased tension in the DDFT created by lowering the heels is adequate. The polyurethane shoe (Polyflex®) provides another option to use with mild upright foot conformation due to its compliance of the flexible shoe with any DDFT tension and the mild heel elevation present in the shoe, which is enhanced by creating breakover in the shoe with a grinder (Robert Hunt, DVM, personal communication).

Farriery for a high hoof angle with concurrent phalangeal misalignment is a greater challenge. The object of farriery is to realign the distal phalanx within the hoof capsule, load the heels, and compensate for the shortening of the DDFT, all of which will improve the HPA. Therefore, farriery is directed at lowering the heels, but the amount to remove can be hard to determine. In mild to moderate clubfeet, the amount of heel to be removed can be estimated by placing the thick end of a 2° or 3° pad under the toe of the foot and allowing the horse to stand on it. If the horse does not resent the tension placed on the DDFT, the thickness of the degree pad can be removed in a tapered fashion starting at the widest part of the foot. The toe is shortened by backing up the dorsal hoof wall with a rasp. The trimmed foot is fitted with a shoe that has the breakover forged or ground into the shoe starting just dorsal to the apex of the frog and tapering toward the toe to further decrease the stresses on the DDFT.

A clubfoot with a marked flexural deformity should still have the heels trimmed in order to load the heels and unload the toe. However, heel elevation must be added to the shoe or incorporated into the shoe to compensate for the shortening of the musculotendinous unit. The necessity of adding heel elevation will also be evident if the horse had a toe-first landing pattern noted during the initial examination prior to the farriery. This can be determined following the trim by placing the trimmed foot on the ground palmar to the contralateral limb to observe for any space between the heels of the foot and the ground (Fig. 13A). The author uses a wedge shoe or places a wedge pad or a bar wedge between the heels of the foot and the shoe to compensate for the shortening of the tendon unit. If a wedge shoe is selected, silastic material should be placed over the solar surface between the branches of the shoe to support the sole which will be higher off the ground. This method allows the heels to be weight-bearing but at the same time decreases the stresses in the muscle tendon unit. Breakover is applied as described above (Figs. 13B and 13C). Severe flexural deformities that result in chronic lameness can be treated by performing an desmotomy of the accessory ligament of the DDFT combined with the appropriate farriery described above.9,22

7. **Sheared Heels**

Sheared heels is a hoof capsule distortion resulting from displacement of one heel bulb proximally relative to the adjacent heel bulb.12,13,23 This disparity between the lateral and medial heel bulb is generally 0.5 cm or more. The displaced bulb is predominantly seen on the medial side but can be seen on the lateral side. Sheared heels appear to develop as an adaption-distortion of the hoof capsule as a
consequence of limb conformation that results in an abnormal strike and loading pattern of the foot on the ground. The author believes that when the adaptive ability of the hoof capsule is surpassed by the excessive load on one section of the foot, the ensuing type of hoof conformation can be a source of unilateral palmar foot pain and predisposes the foot to subsolar bruising, corns, quarter cracks, fracture of the bar, and deep fissures within the base of the frog (Fig. 14). This foot conformation is readily observed by standing behind the horse and noting the relative distances measured from the heel of the hoof capsule to the hairline at the bulbs of the heels and noting any difference between the lateral and medial heel. Observing the displaced heel/quarter from the side, the wall will be straighter due to increased load and may start to roll under; the coronet will be displaced proximally and assumes a more horizontal appearance, and there will be tightly packed growth rings below the coronet (Figs. 15A and 15B). Biomechanically, the position of the coronary band is related to the balance between hoof wall growth at the coronary band and the rate of migration of the hoof wall distally (Andrew Parks, personal communication 2017). Furthermore, the rate of migration of the hoof wall is a balance between an active process occurring in the lamellae to cause them to move distally and the force on the wall from the GRF. The increased load on a given side of the foot over time appears to result in biological remodeling rather than the heel being pushed proximally, in other words, the heel is “growing” out of shape rather than being pushed out of shape (Figs. 16A and 16B). There is a correlation between limb conformation in which the limb has a rotational deformity that changes the flight pattern of the limb and ultimately the manner in which the foot lands. When observing the horse in motion on a firm surface, it will be noted that the horse lands or contacts on one side of the foot (generally laterally) and then loads the other side of the foot. Looking from behind the horse, the direction of the carpus at break-
over will be lateral, causing the horse’s foot to strike the ground prior to impact at an arc rather than flat.

Farriery

Farriery is directed toward unloading the hoof wall and decreasing the forces on the displaced side of the foot. Because many horses with sheared heels will have a toe-out conformation, traditionally, farrier practices have advocated trimming the horse’s heels so the ground surface is lower on the opposite side from the side being displaced proximally. Intuitively, if the heel is longer on the displaced side (measured ground surface to hairline), it is reasonable to trim the displaced side. When possible, the author likes to remove the shoes and stand the horse on a hard surface for 24 hours prior to the farriery, as this allows the affected side of the foot to settle into a more acceptable conformation.

Farriery is initiated by removing the shoes and again observing the horse walking on a hard surface, noting the strike pattern of the foot. The author will use a double-trimming method in an attempt to improve and unload the distorted quarter/heel. As described previously, the trim begins with a line drawn across the widest part of the foot with a magic marker. The frog is trimmed to where it is pliable and the quarters and heels of the hoof capsule from the middle of the foot are rasped palmarly so the heels of the hoof capsule and the trimmed frog are on the same plane if possible. An attempt is made to create as much ground surface under the affected heel as possible, which will often result in more ground surface on the displaced side, which may make that side marginally lower than the other side of the foot. The toe and quarters are reduced appropriately so when the trim is completed, the surface area on either side of the line drawn or the widest part of the foot will approximate each other, resulting in a proportional foot (Fig. 17). Trimming the quarter/heel on the displaced side of the foot is logical, as it is the taller heel and it increases the ground surface of the foot on that side. Following the trim, the horse is again walked on a hard surface and some improvement in the landing pattern is generally noted.

If the displacement is significant, the author’s choice is a wide, web steel, straight-bar shoe fitted symmetrically to the trimmed foot (Fig. 18A). Bar shoes effectively increase the surface area of the foot, allow the palmar/plantar section of the foot to be unloaded, and decrease the independent vertical movement at the bulbs of the heels. If the displacement of the quarter/heel is marginal, an open-heel shoe can be used, but the trim remains the same.

Before applying the shoe, a second trim is performed under the proximally displaced quarter heel, which goes from 0 mm at the ipsilateral toe (e.g., inside toe for medial sheared heel) to an average of 7 mm at the affected heel. The amount of heel that can be

Fig. 16. A. An illustration showing the balance between the growth of the hoof wall and its migration toward the ground, which is countered by the force on the hoof wall. B. Shows the COP moved to the overloaded side of the foot, which can be addressed by the appropriate farriery (Courtesy Dr. Andrew Parks).

Fig. 17. A proportional foot with approximate distances (black line) on either side of the widest part of the foot (red line). Note increased ground surface trimmed under displaced heel (yellow arrow).
taken off in the second trim depends on the sole depth at the seat of corn and on the severity of the proximal displacement of the coronary band at the sheared heel. The amount of horn, under the sheared heel, which can be taken off with this second trim, ideally corresponds to the difference in length/height between the two heels. Lowering the hoof wall at the quarter/heel will create a space between the shoe and the hoof wall on the displaced side of the hoof (Figs. 18B and 18C). This improves the landing pattern, unloads the affected heel, and allows the heel bulb to settle down and assume a more acceptable position. Feet with a low palmar/plantar angle rarely have enough sole depth under the affected heel for the second trim; in these cases, the rest of the hoof wall can be raised with a full leather or synthetic pad and impression material. Impression material is placed in the palmar section of the foot from the apex of the frog palmarly except under the displaced heel/frog sulci where the second trim was performed. After the shoe is attached to the foot, the affected heel will rapidly descend onto the shoe, making the original space created by the second trim between the hoof wall and the shoe disappear. As most horses with a sheared heel have a predisposing limb conformation (e.g., a rotational deformity), these feet have a tendency to continue to deform the affected heel proximally and the double trim method usually has to be applied to some degree at each consecutive shoeing. Horses with this type of hoof conformation should be reset at 4–6-week intervals.

8. Mismatched Feet

The management of mismatched hoof angles remains a controversial subject for both the farrier and veterinarian. Mismatched feet could be defined as forefeet conformation that have a high or upright hoof angle on one foot and a low hoof capsule angle on the contralateral foot (Figs. 19A–C).21,24 The difference between the forefeet could range from a high hoof angle with a straight HPA to a clubfoot with a flexural deformity and an overloaded low heel on the contralateral limb. The mass, integrity, and difference in heel height will be the contributing factors to the mismatched dorsal hoof angles (Fig. 20). Limb length disparity has been suggested as a cause for mismatched feet, although it has not been scientifically proven. Mismatched feet may contribute to poor performance, subtle lameness, and a shortened anterior phase of the stride on the upright foot. Traditional farriery seeks to elevate the heel on the low foot and therefore match the forefeet. However, this practice should be discouraged and

Fig. 18. A, A steel straight bar shoe with the nailing pattern for a sheared heel. B, Shows the platform created under the heels by the bar shoe with the medial heel unloaded. C, Shows the space created under the displaced heel at breakover. Note the displaced coronet and the hoof wall defect present.

Fig. 19. A, Shows the difference in dorsal hoof wall angles in a pair of mismatched forefeet. B and C, A side view of a pair of mismatched forefeet where the LF has a low angle while the RF has an upright angle with a mild broken forward hoof pastern axis.
treatment should be based on farriery principles to improve the structures and function of the individual foot. Observation again begins by standing the horse on a firm flat surface. Looking from the front, the hoof with the upright hoof angle will be narrower than the hoof with the low hoof angle. The HPA should be evaluated from the side with the third metacarpal bone always perpendicular with the ground. It should be determined whether the foot with the high hoof angle has a straight or broken forward HPA and whether the foot with the low angle has a straight or broken backward HPA (Figs. 21A and 21B). If the foot with the high hoof angle has a broken forward HPA, it should be considered to have a flexural deformity or a clubfoot (Fig. 21C).

Looking at the heels from behind, the integrity of the structures in this area should be evaluated and the difference in the height of the heels should be noted. It is also important to note whether the frog is recessed between the heels of the hoof wall on the foot with the high hoof angle and whether the frog is prolapsed distal or palmar to the hoof wall on the foot with the low hoof angle. Looking at the bottom of the foot, it is helpful to visualize a line drawn across the widest part of the foot and look at the proportions of the foot on either side of the line. Again, it is important to note if the frog is distal to the hoof wall or whether the frog is recessed below the heels of the hoof wall. The frog being recessed causes impaired function in the palmar section of the foot and places the entire load on the hoof wall. The horse should be evaluated in motion at both the walk and the trot. First and foremost, it is important to rule out any lameness. It is especially important to evaluate the landing pattern of the forefeet, as the foot with the high hoof angle will often land toe first rather than flat. Lastly, the horse should be trotted to note whether the horse has a shortened stride on the high-heeled foot. It must be remembered that a shortened stride on one limb will cause the opposite foot to be on the ground longer, which, over time, may create further damage to the heel structures of the foot, with the low heel resulting in a flat “panned out” low foot angle.

Farriery
Horses with a disparity between dorsal hoof wall angles will generally have a straight HPA and the hoof wall growth below the coronet from the toe to the heel will be even. In this case, the author suggests using good farriery principles to apply the appropriate trim and shoe for each foot on an individual basis. These basic farriery principles include the following:

- Using the HPA.
- Using the COR as a guideline for trimming and placement of the shoe.
- Trimming the heels to the base of the frog or to the same plane as the frog.

Managing horses with mismatched feet where one foot has a high hoof angle with a flexural deformity or a clubfoot becomes more complex. This type of case will often present with a shortened stride on the limb with the upright foot. Low or compromised heel structures may be noted on the opposite foot from overloading the heel on that side due to the shortened stride placing excess weight on that foot over time. Managing these horses can be difficult and the proper shoeing protocol may not be inherently obvious. Again, it must be emphasized that each foot should be approached on an individual basis.
basis (Figs. 22A, 22B and 22C). It is common to see horses with mismatched feet shod with two different size shoes; often a smaller shoe is used on the upright foot. This practice should be discouraged, as the ground surface on both forefeet should be the same.

Farriery for the clubfoot has been discussed previously in this paper. When approaching the foot with the low angle, the clinician is often inclined to wedge up the heels to improve the HPA. However, this will place more stress on the already compromised heel structures. Although the HPA will appear improved immediately following the shoeing, the long-term effect is exacerbation of the low angle, further crushing of the heels, and prolapse of the frog below the ground surface of the foot. Alternatively, the heels should be trimmed back to the widest point of the frog if possible, or an attempt should be made to get the hoof wall at the heels and the frog on the same plane. As much toe length as possible should be reduced, generally using the dorsal hoof wall, as there is usually decreased sole thickness in the foot with a low heel. It should be emphasized that when possible, it is extremely important to obtain good quality radiographs prior to trimming to determine the amount of heel and especially sole that can be removed. Breakover, such as a rolled toe or a rocker toe if there is adequate sole thickness to allow it to be trimmed into the foot, is very beneficial, as it will further decrease the leverage at the toe on the low-angle hoof. The COP on a low-angle foot is further palmar than that of the upright or normal hoof, therefore, the shoeing protocol is directed at moving the COP away from the overloaded heels. Additionally, redistributing the load or load sharing with the weight-bearing structures of the low-angle foot may help to decrease the forces directed to the heels. This can be accomplished with impression material, a pour-in pad, and a spider plate or a heel plate added to the palmar aspect of the shoe.

9. Conclusion

The clinical examination of the equine foot has been well described and is generally performed in lameness cases. Evaluation of the hoof capsule during the lameness examination will not only provide additional information as to the etiology and treatment of the lameness but will also serve as a guideline to apply therapeutic farriery and other preventive measures to maintain a healthy hoof. The morphology of the hoof capsule reveals deformation and changes in growth that occur following increased or reduced force. The relationship between the limb and the foot indicate conformations that predispose the foot to abnormal weight bearing. Inversely, using the abnormal distribution of forces and the subsequent hoof capsule distortion as a template, appropriate farriery or therapeutic farriery will form at least part of the treatment plan. Here, it is essential for the clinician to be familiar with the biomechanics of the foot and how these forces can be altered to change the distribution of forces or the focal stresses on a given section of the foot.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Assessment of the Foot When Shoeing a Horse with Poor Performance

Mark Silverman, DVM, MS

Not all effects of suboptimal shoeing will result in obvious lameness. Often, there will be more subtle effects, such as a limitation in a dressage horse’s ability to move laterally for a Grand Prix-level half-pass or a jumper’s willingness to turn left following a big oxer. By taking advantage of information garnered using digital radiography with metric analysis, close clinical evaluation, familiarity of biomechanical concepts, high-speed video, and an awareness of the demands of a specific sport, shoeing can be optimized to allow for improved performance and potentially improved longevity. Author’s address: Sporthorse Veterinary Services, PO Box 990, Rancho Santa Fe, CA 92067; e-mail: hoofdoc@mac.com. © 2018 AAEP.

1. Introduction

Therapeutic shoeing has been used as part of the treatment regimen for many foot- and limb-related lameness issues. The physical manipulation of dorsal-palmar/plantar and medial to lateral hoof balance is a mainstay of all quality shoeing applications. In addition, we can affect the break over or heel lift mechanics of the hoof, the traction provided by the shoe, and alter the way in which the shoe interacts with the substrate on which a horse works. By factoring in the demands of a sporting endeavor and possessing a working understanding of distal limb biomechanics, we can use digital radiography, high-speed cinematography, and thorough clinical assessment to improve an athlete’s ability to perform at his/her peak potential with a decreased potential for injury.

Biomechanical Factors

Evolution has allowed the modern horse to adapt to the challenges of contemporary environmental and nutritional resources. In adapting to the modern form, the horse has adjusted its ability to accommodate turns and irregular surfaces. To gain efficiency, the modern distal limb has focused the ability to accommodate medial to lateral flexion to movements within the pastern joint, coffin joint, and hoof capsule deformation. These factors have a direct bearing on our approach to shoeing the modern sport horse.

Recognizing the demands placed on the pastern and coffin joints and the hoof capsule to accommodate the irregularities of terrain and mobility, we can fine tune our shoeing to limit the magnitude of the biomechanical challenge to these critical structures.

2. Materials and Methods

Clinical Assessment

When inspecting the horse with the purpose of optimizing performance, it is best to begin with a thorough assessment of the patient. Taking time to obtain some knowledge of the general conformation...
Closely interrelated.

Stresses, whether internal, external, or a combination of the two, that create a distal wall flare may also be displayed as a modification of the shape of the sole and the heel structures. As an example, divergence of the distal dorsal wall (dorsal flare) from the P3 may be the result of a functionally short deep digital flexor tendon (DDFT). This condition, often called a clubfoot, a flexural limb deformity, results in a battle between the tension of the DDFT and the dorsal laminar structures, both having some effect on the position of the coffin bone within the hoof capsule. The ground reaction force, acting to push up on the ground surface of the hoof wall, and the excessive tension of the DDFT, working to move the P3 around the center of rotation of the coffin joint, will result in the distal dorsal wall deforming and stretching of the distal portion of the laminae. In addition, the displacement of the P3 will result in pressure on the cranial portion of the sole, deforming the sole and leading to a flat cranial portion of the sole that has thinned as a result of the increased pressure and offers limited protection to the deeper structures of the foot. This same foot may have an upright, tall heel structure as a result of the forces caused by the excess DDFT tension. The existence of flexural or rotational deformities often leads to mismatches between stress and the mechanical integrity of the foot structures. The tendency is for the deformity to ultimately result in the weightbearing surface of the hoof capsule to arrive at the approximate center of pressure of the limb. Often, this process will result in deformation of the hoof capsule. The imbalance between stress and structural integrity will lead to complexes of capsule deformity. Varus deformities may lead to medial wall flares and overloading of the lateral quarter. Valgus deformities may lead to lateral toe flares and overloading of the medial heels. There can be many variations of this form of capsule distortion.

Irregularities of the hairline are often early warning signs of irregular loading of the hoof. Where we expect a smooth curvilinear shape of the hairline from the dorsum of the hoof to the heel bulbs, we sometimes see an abrupt alteration of the curvature of the hairline, often occurring toward the caudal portion of the hoof. This distortion often aligns with the placement of the heel portion of the shoe under the caudal portion of the wall. For an individual with short, underrun heels that is shod with short branches, this is a common malformation. The heel structure of the underrun hoof tends to have weak structure and is often found in combination with a long, low-angle toe, lending to greater challenge on the heel structures. In addition to heel distortions, we often see an upward vertical displacement of the medial or lateral wall made evident as a displacement of the hairline. This form of distortion can often be traced back to conformation. Rotational deformities, angular limb deformities, and flexural deformities may lead to asymmetrical wall loading and ultimately hairline asymmetries. Other potential causes of hairline distortions may be secondary to trimming issues or even lameness issues, leading to uneven loading of the hoof capsule. As an example, a horse with a chronic lameness of the left pelvic limb will tend to place the stronger, less compromised right pelvic limb toward the midline. This adaptation may result in an overloading of the lateral heel of the stronger limb. The overloaded lateral heel quarter will display slower growth along with excessive wear if the horse is unshod. The net result is a horse with a right hind foot that is high medially with a lateral heel that is worn or damaged. An additional source of hairline distortion can occur with normal, symmetrical loading of the hoof capsule but compromised structural integrity of the laminar connection of the hoof wall. A medial sinker may have a proximally displaced medial hoof wall, along with distal displacement of the medial coffin bone. Although the loading experienced by the hoof may be symmetrical, the damaged medial laminar junction cannot adequately manage the load and displacement occurs.

Growth ring anomalies are an additional indicator of loading or structural abnormalities. Compressive forces acting on the hoof may result in alteration of the growth rate of the affected hoof wall. Conformation leading to excessive loading of a portion of the hoof wall may result in creation of a flare, displacement of the hairline, or compression of the growth rings, or a complex involving all three, in the region of overload. The factors that lead to growth ring asymmetry will be the same as those discussed in the earlier portion of this section. One addition
to the list of potential factors affecting hoof growth abnormalities not directly mentioned above would be compromise in blood supply.

During the clinical examination, take note of how the horse stands. Be aware of a tendency to point one foot or place a foot axial or abaxial to the expected position. Often, the patient will place the foot in the direction of the high spot in the trim or to reflect a stress occurring when the foot is placed in an expected, normal position. A thorough hoof tester examination will complement the pool of data already collected, revealing a sore medial or lateral heel, or perhaps a thin sole, lending limited protection to the deeper sensitive structures of the foot. Something as simple as a bravely placed nail due to thin walls or previous wall damage may be revealed during a hoof tester examination. The methodical use of the hoof testers may also suggest pain in the core structures of the foot, displayed as a pain response to pressure across the hoof capsule at the level of the navicular bone.

Assessing static balance and picking up and sighting each foot might reveal additional useful information. The tendency to pull the limb out of its natural path of motion when assessing static balance must be avoided. Feel the passive range of motion through the flexion and the extension of the joints from the carpus to the distal interphalangeal joint in the forelimb and through the fetlock to the distal interphalangeal joint of the hind limb. Pulling the limb to a position of convenience or comfort for the examiner will limit the usefulness of the findings of the examination. Noting an unexpected component of the limb’s passive flight path may reveal conformational anomalies that will require accommodation. A horse that displays a tendency for the distal portion of the forelimb to track towards the contralateral hind limb as opposed to the ipsilateral hind limb may have a rotational deformity at the level of the carpus. This horse’s break-over alignment will reflect this deviation. The natural alignment of break over should be accommodated as opposed to being challenged to follow some preconceived notion of what is “correct.” While the foot is up, evaluate the horse’s sole; is the sole cupped or unnaturally shaped? A flattening of the sole may suggest a distal displacement of the coffin bone or poor structural integrity of the hoof capsule. If the sole is flat and there is evidence that it is not simply an unshed double sole, radiographs may be useful to evaluate the position of the coffin bone and to establish proper support for the foot. Is the frog of expected length and position or does a short, deep frog support the finding of a subtle flexural deformity? Is there symmetry around the center of the coffin bone (indicated by Duckett’s dot) of the foot or is there excess mass in one quadrant? Even subtle details expressed through the foot’s architecture may have significance and may be addressed by modifications in the approach to shoeing.

Once a static evaluation of the horse is complete, it is time to observe the patient in motion. This involves watching the horse at the walk and trot in hand on hard ground. Watch for soundness issues to determine if this shoeing session may need to be preceded by a lameness evaluation. Observe foot placement and flight path for each limb. We often speak of a flat foot landing, which, depending on the level of acuity used, rarely occurs. At our visual limit of approximately 20 frames per second, (this is an accepted number that allows for useful interpretation of the image), a symmetrical heel landing may be apparent. When using high-speed video and the landing of the foot is viewed at a frame rate of 240 frames per second (Fig. 2) or greater, we will often note a unilateral heel landing. With close observation, it may become apparent that the foot undergoes an initial landing at one region with a secondary loading of a diagonally opposite portion of the foot. Although it might be tempting to focus on the initial contact point of the foot, it is often the secondary loading area that experiences the greatest trauma. The goal is to adjust the trim and shoe application to minimize the focal loading of the secondary point. This may be best achieved by adjusting the break-over mechanics and altering the shoe to spread the load over a larger region at secondary loading zone.

While assessing landing/loading patterns, note the character of break over (heel lift) for each limb.
Is the transition from flat footed to foot flight smooth, or is there a rapid rotational acceleration after initiation of heel lift? Take note of any corrections (i.e., wobble) in the flight path of each foot resulting from nonlinear preloading. Nonlinear preloading may be seen with the earlier example of a horse with a rotational deformity at the level of the carpus. Shoewing a horse with this sort of rotational deformity to have a break-over alignment that is in line with the apex of the frog will lead to stress within the distal joints that will be released at the point of heel lift, resulting in corrections in alignment occurring during the flight phase of the hoof. Findings of this nature suggest stresses on the distal limb that may be addressed in the shoeing approach.

The overall goal for performance-optimized shoewing is to limit unnecessary stresses experienced by the foot and distal limb. Adjusting for focal loading patterns through recruitment of greater portions of the foot will limit local overload of specific structures. Smooth, linear transitions from phase to phase of the stride are a visual method to clinically appreciate appropriate shoeing and trimming for longevity and performance.

High-Speed Video
High-speed video is a tool that is readily available in today’s technologically advanced society. Everyone with an iPhone has all the technology needed to use high-speed video as an aid in an evaluation of the horse. There are two methods of using high-speed video, quantitative assessment and qualitative. Qualitative assessment is the only practical method for clinical practice. The video camera can be used as a stand-alone device to expand time and allows us to see what the naked eye cannot. Details of the hoof's landing pattern, loading pattern, and flight path that the eye might miss can be seen and reviewed as needed when time is expanded 10-fold or more. Nonlinear patterns of break over can be visualized, as can asymmetrical loading of the hoof wall. In addition, we can also more easily appreciate the rate of angular change immediately following heel lift, something that may be difficult to observe with the naked eye. Quantitative assessment, while great in concept and can help to produce metrics for the factors affecting the foot, requires elaborate setup and calibration plus the ability to access the data frame by frame to arrive at useful information. This is a tool that is best left for research. By comparison, during a routine assessment of a patient, I can easily bring out an iPhone and improve the ability to observe from a qualitative perspective. An example where slowing down the image may be useful would be observing how a particular patient negotiates on hard ground. The naked eye may appreciate a subtle head bobbing lameness on the right fore when circling in a clockwise direction. High-speed video, when played back to enable slow-motion viewing, would allow the viewer to appreciate that the patient may not have the range of motion in the right fore pastern and coffin joints to allow for the medial heel of that hoof to come into contact with the ground. Altering this patient’s break-over alignment through trimming, the use of half round stock, or a creative grind of the web may help this patient to better negotiate tight turns to the right.

Digital Radiography
For podiatry, radiographs are an important window into the inner details of the foot and are the imaging modality of choice. The horizontal dorsal to palmar/plantar and the horizontal lateral to medial radiographic views are the “bread and butter” of equine podiatry. Although there are a number of quality resources available describing the in-depth process for creating useful radiographs for podiatry, it is important that we review some key factors.

The creation of useful podiatry radiographs requires careful preparation and positioning of the foot. The ability to produce repeatable, high-quality images with minimal magnification is crucial for assessment and evaluation of the shoeing process over time. Markers should be permanently set in the blocks used for setting the foot at the appropriate height for the generator to indicate the support surface, (Fig. 3). The blocks should be made to match with the design of the generator, having the center of the beam align with the bottom of the coffin bone. The common block design for lameness diagnostics is set up to allow the beam to center on the navicular bone. In addition, marking the junction of the hoof capsule and hairline at the dorsal and caudal portion of the hoof and the apex of the frog with barium paste also proves useful in obtaining metrics for an evaluation of the foot. Alignment of the generator and imaging sensor must take into account the patient’s conformation. Pay attention to the alignment of the rotation of the coffin joint, being careful to align the beam perpendicular with the center of rotation of the distal
interphalangeal (DIP) joint. There is often a rotational malformation of the limb that requires an adjustment of the alignment of the generator and receptor to result in the optimal view. The work environment proves to be an ongoing challenge, as having a proper work area with a flat, level floor and adequate space for the patient and positioning of the generator is required to achieve the appropriate views. In addition, it is important to have the patient stand in his/her normal posture, loading the paired limbs equally and not standing artificially base wide or narrow. Even the position of the horse’s head at the moment of exposure can produce measurable effects on joint alignment.

Once adequate podiatry views have been created, there are many metrics that can be defined. The essential metrics for podiatry evaluation are given below:

- Evaluation of the horn laminar zone (HLZ), proximal and distal.
- Depth of the sole at the dorsal distal margin of the P3 and height of the sole cup at the same location.
- The palmar/plantar angle of the P3.
- The axis of the DIP joint (P2 to P3 alignment).
- The angle of the dorsal hoof wall.
- The angle of the dorsal P3 wall.
- The heel height.
- The heel angle.
- The toe to foot ratio (Fig. 4).
- The coronary band to extensor process (founder) distance.
- The medial to lateral symmetry of the pastern and coffin joints along with the balance of the coffin bone to the ground surface.
- An additional metric that the author finds useful is the angle of deflection of the DDFT at the navicular bone (Fig. 5).
- Given the high image quality afforded by contemporary digital systems, it is also possible to appreciate the alignment of proximal margin of the stratum medium at the region of insertion of the coronary papillae to the indentation in the P3 where the extensor process blends into the relatively flat surface of the P3. This can offer an early indication of displacement of the P3 within the hoof capsule (Figs. 5 and 6).

With the metrics listed, a reasonably comprehensive functional image of the foot can be created and changes resulting from trimming and shoeing can be evaluated. In the essentially sound horse, we would not expect to find any one metric to be radically out of the norm, but, over time, with many repetitive loading cycles, small stresses may add up to have a noticeable effect on performance. For example, a mild 1 or 2 mm increase in HLZ distally as compared with proximally may indicate stress within the dorsal wall, associated with a long toe/low heel conformation. Although a subtle deviation may not result in pain as that experienced with laminitis, it may affect the patient’s willingness to perform at an extended stride or land from a large jump. This same sort of subclinical effect might also occur with a medial to lateral imbalance of the distal joints of the limb or a conformation leading to a tight angular displacement of the DDFT around the navicular bone, such as a broken back axis of the

Fig. 4. Toe to foot ratio = A divided by C. The blue line indicates the center of rotation of the DIP joint.

Fig. 5. Red lines indicate the angle of deflection of the DDFT.

Fig. 6. Anatomical image showing the P3 at the extensor process and the proximal stratum medium.
coffin joint, a large toe to foot ratio, or a low palmar/plantar angle. Similarly, finding a foot with low heel angle along with low heel height may not cause immediate lameness but unless addressed, may result in caudal foot pain secondary to structural damage or stress within the navicular complex.

Environmental Factors
There are additional factors to address when trying to complete this puzzle. The type of work performed, along with the surface on which the athlete performs, have potentially significant effects on the approach to shoeing an athletic horse.

For the horse working at speed, the weight of the shoe is an important consideration. Increased mass will not only make it more difficult to accelerate and slow the foot, the mass of a heavy shoe may also affect the flight pattern of the limb, not to mention the additional stress that mass may place on the joints and soft tissue structures. This is the polar opposite of the shoeing applications for the Saddlebred show horse, where the flight pattern and range of motion are the critical factors. The weight penalty associated with the weighted shoes and the pad stacks used in shoeing this type of horse is less of a factor when the horse is not asked to move at great speed, cover great distance, or perform around sharp turns. The demands of each equestrian sport will dictate at least some of the details used when arriving at a shoeing plan. What are the demands for traction? Does the sport require rapid acceleration, tight turns, sliding stops, or adaptations for specific terrain? Does the patient have specific pathologies that require biomechanical adaptations to permit optimum performance?

Many of the alterations that are made to the shoe might address issues experienced while traveling in a straight line. Rolling or rocker the toe of a shoe (Fig. 8) may have the effect of smoothing or otherwise altering the break-over mechanics of a shoe. The challenge comes in taking this adaptation and making it effective in both a straight line and when the athlete is working through a turn to the left or right. Most sport horses seen at the author’s practice spend a great deal of their careers not going straight, although the rocker or roll toed shoeing approach often used is designed to be its most effective when going directly from point A to point B. Going back to the earlier discussion of evolutionary biomechanics, you will recall that some of the greatest challenges to the distal joints of the limb occur when turning or managing uneven terrain. Guiding your execution of the shoe to take advantage of this knowledge and simplify the demands on the coffin and pastern joints may prove to have long-term benefits in your athletes’ soundness.

A final piece to factor into the decision-making process is the type of terrain on which your athlete performs. The challenges experienced by the competitive dressage horse make for a good example. Footing substrates in working dressage arenas will range from sand to turf to sand mixed with synthetics, paraffin, or other binding agents. Sometimes the surface is aerated and “fluffed,” allowing the substrate to conform to the hoof. At other times, the surface of the substrate is flat rolled and partially compacted, having the horse work more on top of the surface than within it. Although the more “open” style of surface preparation allows the surface to adapt to the pressure of the descending hoof, it offers little energy return or “bounce.” The dense
rolled surface may offer greater energy return or springiness but allows little penetration of the hoof, requiring the joints and soft tissues of the athlete to take up more of the challenge. Both approaches to surface preparation can be dramatically altered by the amount of moisture retained within the substrate and may change in character as the day progresses or with changes in the barometer, wind, or cloud cover. With some awareness of the current or planned environmental factors, shoeing can be fine tuned to best accommodate conditions to be experienced at critical junctures.

3. Results
In many of the author’s sport horse patients, it is important to take the long view when addressing the approach to shoeing. Unlike the racing industry or other equine sports where speed is the ultimate focus, most injuries associated with sport horses are secondary to repetitive trauma. Beginning with the static examination, evaluate the information offered by the hoof capsule. Imbalanced stresses, displayed as hoof capsule distortions, may be attributed to foot pathology, conformation challenges, or soundness issues. Flares can often be attributed to imbalanced loading of the hoof capsule. A patient with a subtle flexural deformity may produce excess stress at the dorsal hoof wall due to excessive tension of the DDFT. Stress associated with internal forces acting on the capsule are challenged by ground reaction forces, the opposing force of the ground pushing up toward the patient. As the ground reaction force counters the excessive internal forces, the laminar junction of the wall is challenged and stretches, leading to the dorsal wall flare that is noted on examination. On careful observation, it is also noted that the heels of the affected foot are more upright and the growth rings of the affected foot are divergent toward the heels. In a similar fashion, a patient with a toed-in rotational deformity may develop a dorsi-medial flare and a near vertical lateral wall as sequela to his rotational deviation. The lateral quarter is often taking more vertical load with this conformational distortion and will vertically displace the hairline proximally. The growth rings of this foot may appear to be compressed laterally as overload tends to slow hoof growth. The medial portion of the hoof will grow at a normal rate but will effectively grow faster than the lateral wall. As this foot progresses from the day of trimming, a medial to lateral imbalance will develop. The lateral wall, as stated earlier, will become more vertical, and the medial wall will develop a greater slope that will eventually lead to a dorsi-medial flaring.

When examining the hoof capsule, attempt to visualize the stresses that might lead to the flares, hairline distortions, and growth ring anomalies being displayed. Appreciate the distortions of the hoof capsule relative to the skeletal structure of the distal limb. Once recognized, it is often possible to let the hoof tell you a story and allow you to better understand how the capsule got to its current state. During the static evaluation, take a moment to notice the horse’s posture. How he places his feet may add additional insight to subtle details of the existing foot balance or discomfort. By compiling information gathered through a thorough static examination and adding any knowledge of existing distal limb pathology, such as laminitis, ringbone, or collateral ligament injury, the details of what must be addressed during the shoeing process start to take shape. Alter the approach to shoeing this individual to limit the effects of the adverse stresses that you have defined.

With high-quality balance radiographs (Fig. 9 and 10) in hand, study the metrics to see if they fall into expected and desired ranges. Often, problems with the metric analysis will coordinate with the distortions displayed by the hoof capsule, allowing a clear pathway to improvement.

Finally, before picking up a knife, nipper, or rasp, observe the patient in motion. Look at the details of foot landing and loading. Is the landing relatively smooth and flat, or is there a clear pattern of initial strike at one portion of the foot with a resulting loading of a second, often diagonally opposite,
portion of the foot? Although I am not suggesting that this can be corrected in many cases, this detail can be factored into the shoeing plan to minimize negative effects of such a conformation. Distortions of the flight path of the foot or rotational corrections occurring during the flight phase of the stride may also be addressed in your shoeing plan to help minimize negative effects. Some of these flight phase anomalies may require a simple reassessment of break-over alignment to yield improvement. While observing the horse in motion, notice the foot placement. Try to appreciate any abnormal foot placement, such as an unexpected base wide or base narrow footfall, that may indicate an adjustment made by the horse to avoid discomfort in some portion of the foot or distal limb. One last factor to this complex formula is developing an appreciation of the rotational acceleration of the foot at break over, or heel lift as the author prefers to call it. Rapid snapping of the foot off the ground suggests a delay in heel lift and potentially places additional stress on the structures associated with the navicular region. Smoothing out the heel lift or break over, is one more detail to add to the algorithm that a well thought out shoeing plan has become. Although many of these details can be seen with the naked eye, using the power of high-speed video can expand our abilities and can be a useful way to document our concerns and the results of our manipulations.

4. Discussion

Although the shoeing of the performance horse is still very much an art, science and technology is finding its way into the process. Month by month, additional understanding of the function and structure of the foot is gained. Incorporation of this greater knowledge along with application of thorough and repeatable methods of assessment may lead to improvements in the shoeing process. Additionally, a consistent and comprehensive approach to the shoeing and trimming process will help lead us to a greater understanding of what we know and what we need to still discover.

There is an old quote attributed to Reinhold Niebuhr that went something like this, “... grant me the serenity to accept the things I cannot change, the courage to change the things I can, and the wisdom to know the difference”. Not every foot can be brought back to what we consider to be normal. Our goal is to optimize the function, performance, and longevity of our patient, taking into account possible limitations and minimizing the negative effects that they might otherwise bring.

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Declaration of Ethics

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Conflict of Interest

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References

Navicular Syndrome

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Navicular syndrome is a term that describes palmar foot pain in horses. This pain can be attributed to both osseous and soft tissue structures within the palmar half of the foot. Diagnosis of the problem can be challenging due to the number of structures within this portion of the foot; advances in imaging including magnetic resonance imaging and nuclear scintigraphy have aided in the ability to identify the source of the lameness. There are a number of therapeutic shoeing options and adjunctive therapies available. The ability to diagnose the source of the problem allows the practitioner to tailor the individual treatment approach. Authors’ address: Bur Oak Veterinary and Podiatry, 2830 Old Lemons Mill Rd., Lexington, KY 40511; e-mail: vern@buroakveterinary.com. © 2018 AAEP.

1. Introduction
Navicular syndrome is a term used today when referring to palmar foot pain and pathology of the navicular apparatus in the horse’s foot. This disease is thought to be responsible for at least one-third of chronic forelimb lameness in horses.28 Structures that comprise the navicular apparatus are the navicular bone, suspensory ligament of the navicular bone, impar ligament, navicular bursa, the deep digital flexor tendon (DDTF), and the distal digital annular ligament.1 Commonly, horses affected have either very steep or very low hoof-pastern angles and are usually bilaterally lame. These horses tend to land toe first, and the lameness becomes more pronounced when being worked in a circle.5,27 Horses with histories of heavy work from an early age are at risk of developing navicular syndrome. In addition, breeds such as Quarter Horses, Thoroughbreds, and Warmbloods are commonly affected.1,12

Years ago, the term “navicular disease” was used to describe these horses and usually meant the horse’s career was over. We now know that there are many causes of palmar foot pain1,10,15,26 that are not career ending and some of which do not involve the navicular apparatus. For example, coffin joint collateral ligament desmitis (inflammation) may present as palmar foot pain. This injury is not always considered career ending15 and does not involve the navicular apparatus.

As previously stated, the term “navicular syndrome” refers to a complex array of problems that can cover anything from pain associated with the bone itself to a number of other structures within the foot.

Osseous and soft tissue pain can be isolated problems, but they are often intertwined.1,15 Although there are many medical and surgical modalities to manage disease, this paper will focus on the benefits of therapeutic shoeing.

Anatomy and Pathophysiology of Disease
The navicular apparatus lies within the palmar aspect of the hoof capsule. The navicular bone articulates with distal end of P2 and the proximal end of P3, thus serving as a palmar border of the distal
The suspensory ligament of the navicular bone originates on the abaxial surfaces of distal P1 and proximal P2 and inserts on the proximal border of the navicular bone. The impar ligament attaches the distal border of the navicular bone to the semilunar crest of P3. The navicular bone has a very important biomechanical function in that it maintains a constant angle of insertion for the DDFT on P3. This creates a mechanical advantage for the tendon that allows it to withstand forces during the propulsion phase of stride when the structures of the navicular apparatus experience the greatest load. The relationship of the navicular bone with the bones of the DIP joint is thought to help dissipate load in this region. The DDFT passes over the palmar aspect of the navicular bone and attaches to the semilunar crest of P3. The shared attachment of the impar ligament and the DDFT make it difficult to distinguish which one, if not both, is the primary problem. Between the tendon and the palmar aspect of the navicular bones lies the navicular bursa, which facilitates a gliding surface for the tendon. During the extension phase of the stride, the DDFT and the distal digital annular ligament contribute to the stability of the DIP joint. The palmar aspect of the bone is covered by dense fibrocartilage. This fibrocartilage and the navicular bursa help protect the bone from wear associated with the DDFT. During the propulsion phase of the stride, the DIP joint is at maximum extension and the DDFT exerts more pressure on the distal one-third of the navicular bone. This leads to increased contact between the bone and P2 and increased strain on the suspensory ligament of the navicular bone. Friction between the surfaces of the DDFT and the navicular bone can not only lead to wear on the navicular bone but also to fibrillation of the DDFT itself. This can lead to the development of adhesions between the two structures. In addition to mechanical trauma, it has also been shown that the increased pressure on the bone can disrupt chondrocyte metabolism and lead to cartilage degradation. This loss of fibrocartilage is one of the most commonly recognized lesions in horses with navicular syndrome.

Two main theories have been postulated to explain the cause of navicular syndrome: ischemia of the bone and degenerative changes. The ischemia theory has fallen out of favor because researchers have been unable to induce navicular syndrome by interfering with perfusion of the bone, and histological studies of the bone do not reflect changes supporting this theory. There is more evidence to suggest edema formation and venous congestion within the bone may be a source of pathology. One theory suggests that this mechanism contributes to pain in horses as it does in humans. It has been shown that horses with navicular syndrome have decreased venous drainage and marrow pressures are significantly higher than that of control horses. Although MRI studies have detected evidence of this edema and
congestion, these findings have not been confirmed histologically.\(^{18}\)

The changes categorized as “degenerative” are actually more representative of osteoarthritis and degenerative joint disease.\(^{10,11,13,14,29}\) Repetitive biomechanical forces exerted on the navicular apparatus lead to damage of the fibrocartilage on the flexor surface of the navicular bone, which subsequently traumatizes the subchondral bone. This can lead to the aforementioned increases in pressure within the medullary cavity, edema, cyst formation, and osteonecrosis of the bone itself.\(^{1,10,12}\) In addition to changes to the navicular bone, advanced imaging has helped us identify other potential sources of lameness involving the soft tissue structures of the foot. Horses can experience desmitis of the associated ligaments, synovitis of the DIP joint or navicular bursa, and tendonitis/tears of the DDFT, which can cause pain.\(^{10,15}\) Pathologies such as adhesions, avulsion fractures of the navicular bone, and development of enthesophytes and mineralized foci in the components of the navicular apparatus have also been implicated as sources of lameness. The clinical significance of some of these findings is still under investigation.\(^{1,10,27}\)

**Diagnosis**

Most commonly, horses with palmar foot pain “block-out” to a palmar digital (PD) nerve block. Unfortunately, localizing the lameness is often the easiest part of the process. A PD nerve block can desensitize most of the structures within the hoof capsule and, therefore, leave a multitude of possibilities responsible for the lameness.\(^{4,10,26}\) For example, pedal osteitis of the coffin bone wings may present as heel pain and block to a PD nerve block. This is often seen in racehorses and may resolve with rest and therapeutic shoeing.\(^{27}\) Further localization of the lameness can be done by injection of local anesthetic into the navicular bursa or the coffin joint. Once the lameness is localized, the next step is to obtain radiographs. Radiographs may often show evidence of chronic inflammation in the form of osseous changes. However, radiographs are not always conclusive because they do not give diagnostic information about soft tissue structures and osseous changes cannot be identified until there is at least a 40% change in bone density.\(^{35}\) This is a common problem when attempting to diagnose a lesion suspected to be involving the navicular apparatus.\(^{26}\) The author recommends taking six standard views of the digit in order to completely assess the foot.

**Radiographic Views**

- **Lateromedial:** Evaluate sole depth and the boney column alignment and its relationship with the navicular bone and DDFT. Also evaluate the navicular bone for sclerosis, damage to the flexor cortex, and mineralization of associated soft tissue structures.
- **Dorsopalmar:** Evaluate the mediolateral balance of the foot, joints, and the margins of the navicular bone in a normal weight-bearing position.
- **60° downward dorsopalmar view:** Evaluate the margins of P3 and the navicular bone.
- **60° downward dorsolateral-palmaromedial and dorsomedial-palmarolateral:** Evaluate the distal border and the corresponding wing of the navicular bone.
- **Skyline:** Evaluate the medullary cavity for sclerosis, cysts, enlargement of synovial invaginations, and the integrity of the flexor surface of the bone.\(^{35}\)

In recent years, magnetic resonance imaging (MRI) has become an indispensable tool for diagnosing lameness causing lesions within the equine foot.\(^{1,15}\) MRI uses strong magnetic fields and radiofrequency pulses to image with great detail to both bone and soft tissue structures deep within the digit. With the use of MRI, we can tailor our treatment plan according to the pathologic findings.\(^{10,17–19}\) Some horses may benefit from coffin joint or navicular bursa injections, whereas other horses may just need rest. In many cases, therapeutic shoeing may
help those horses diagnosed with navicular syndrome. Unfortunately, one shoeing application does not work for all navicular syndrome cases. The MRI is a very useful tool that allows us to develop a shoeing application specific to the horse. Some common lesions seen when horses with palmar foot pain are scanned with the MRI include the following: desmitis of the suspensory ligament of the navicular bone, navicular bone degenerative changes, deep digital flexor tendinitis, adhesions of the DDFT to the flexor cortex of the navicular bone or to the suspensory ligament of the navicular bone, and impar ligament desmitis.15,27

Therapeutic Shoeing

The author’s main concern when shoeing a horse with an injury to the navicular apparatus is to reduce the stress being placed on these structures. The number of structures that can contribute to “palmar foot pain” can make these horses challenging to manage. Regardless of the specific problem, there are similarities in many shoeing protocols, but these approaches can be further refined if a specific structure is suspected to be the source of discomfort.

Foot Balance

A balanced hoof is the cornerstone to therapy in these cases. Balance encompasses the function and shape of the foot as it relates to the ground and proximal structures of the limb during static and dynamic phases.37 A foot is said to be balanced when it has been trimmed to reach its maximum mechanical efficiency.38 Many cases present with palmar foot pain and chronic hoof capsule distortion, such as sheered heels, under run heels, severe flares, and deep cracks. Often, resolving the distortion through therapeutic shoeing can eliminate the lameness. The farrier should be able to view the radiographs prior to trimming/shoeing the horse. Both lateromedial and dorsopalmar views are important so that the alignment of the bone can be assessed in different planes. The author often takes radiographs before and after trimming to ensure the hoof is balanced. In the author’s personal experience, trimming alone can radically change hoof angle and digital alignment. The DIP joint and the navicular apparatus will be the most directly affected by trimming and shoeing,7 and so therapeutic choices need to be based on careful radiographic evaluation and a good, balanced trim.

Breakover

One of the most important aspects of shoeing a horse with navicular syndrome is to provide ease of breakover. Breakover is a term used to describe the moment the heels lift off the ground and the hoof pivots over the toe. Although studies have indicated rolled toe, rocker toe, and square toe shoes do not significantly change the duration of breakover from a flat steel shoe,24 one study showed that a long toe created a longer breakover duration.22 Furthermore, reduction in the moment arm of the DIP joint through the use of rolled or rocker toe shoes may not significantly change the duration of breakover but may have a reduction in stress placed on the DDFT and supporting ligaments of the navicular bone during dorsiflexion and at the point of breakover. The author’s goal is to move the breakover point at the toe toward the center of the foot to reduce the force being placed on the navicular apparatus. Other shoeing modifications may be required to provide comfort to these patients.

Wedging and its Effects

Wedging the heels is helpful in managing injuries associated with soft tissue injuries of the navicular apparatus. Wedging has been shown to decrease the force of compression of the navicular bone by the DDFT.21,22 Injuries of the impar ligament, suspensory ligament of the navicular bone, and the distal portion of the DDFT are all shod in a similar fashion. The theory of wedging the heel to decrease tension on these structures, in the author’s opinion, has been helpful in treatment. Wedging is not without complications. This strategy places the heel structures under more loading force and may be further compromised in a horse with an already low angle hoof or crushed heel.23,31 Aggressive wedging also leads to an increase in pressure within the DIP joint.25 Stress on the impar ligament of the navicular bone and distal portion of the DDFT have been shown to be the highest during dorsiflexion.3 The degree to which the foot is wedged needs to be decided in context of the conformation and structural integrity of the hoof in addition to its radiographic appearance.

Another way to achieve the effect of the wedge is to change the surface area of the shoe. When a horse moves in soft footing, the web (width) of the shoe will alter how much the foot sinks into the ground. By using a shoe that has minimal surface area in the front of the shoe and more surface area in the palmar half, we effectively create a wedge because the toe will sink in further than the heel.36 This is a great solution for a horse with crushed heels whose foot might be further compromised by a traditional wedge. An open-toed heart bar would perform this task.

A good example of a shoe that accomplishes multiple goals would be a Morrison Roller Motion shoe with a heel plate welded in the palmar half of the foot. This shoe provides excellent breakover and heel elevation, the heel plate will provide the desired heel protection, and the durometer of the chosen impression material will determine the amount of load placed on the frog.

Managing Osteogenic Pain

Cases showing navicular bone edema or sclerosis are often sensitive to concussion or vibratory forces from impact. In these cases, direct pressure over the central frog has been shown to cause pain.19 Addi-
tionally, compression of the navicular bone by the DDFT may attribute to progression of lameness. The author’s experience has shown that a soft composite pad between the shoe and the foot to dampen the concussion has been helpful in these cases. There are a variety of two-part impression materials or silicone hoof gels available that can be used to manage concussive forces and help redistribute load. These materials come in different durometers (hardness), which is helpful when managing a specific problem. For example, a firmer impression material will provide support but may make a horse uncomfortable if it creates pressure in a sensitive area such as over the frog. Softer materials do not provide as much support, but they may be useful in creating artificial sole depth or dampening concussive forces. Protection of the palmar aspect of the foot with a bar or heel plate can be beneficial. However, it is important not to apply pressure to the frog with the bar or heel plate, as this will most likely make the lameness worse. Filling the dead space between a heel plate and the foot with a softer impression material would help accomplish the intended goal, whereas a firm impression material could cause discomfort. Some shoes are now made with synthetic materials that help absorb concussion as well.

Load Distribution
A shoe can be selected and modified to unload compromised structures and preferentially load stronger areas of the foot. Egg-bar shoes have traditionally been used for the treatment of navicular disease. Although the egg-bar shoe does not affect the stress placed on the navicular bone by the DDFT in normal horses, it has been shown to decrease that stress in horses with navicular disease having a low angle hoof. Possible reasons for this include the redistribution of weight across the heels and added length of the shoe, preventing overextension and further compression of the navicular bone. The shoe should have heel extension to a point perpendicular to a vertical plumb line dropped from the heel bulbs. Load distribution can also be altered by where support materials are placed. They can be placed in stronger areas of the foot and avoided in areas, such as the frog, where the horse may resent pressure.

Medical and Surgical Options
Navicular syndrome affects a large population of equine athletes. Fortunately we have tools at our disposal to help diagnose and treat these patients. Conservative medical management could involve a combination of nonsteroidal anti-inflammatory drugs and/or DIP joint/navicular bursa injection with corticosteroids and hyaluronic acid. The use of bisphosphonates has also been shown to improve clinical comfort. However, when medical treatments and therapeutic shoeing fail to provide comfort to the patient, other options should be considered. There have been a few surgical techniques described, but the PD neurectomy is the most pervasive. This is a surgical procedure that removes a portion of the nerves at the level of the pastern. This treatment is palliative and does not prevent further degeneration of the navicular apparatus. Therapeutic shoeing remains a critical component of the treatment regimen even after surgery has been performed. In fact, this surgery is less commonly performed now due to all the medical advancements and therapeutic shoeing options that are currently available. There can be complications with the surgery such as neuroma formation. A neuroma is a painful tumor arising from nerve tissue at the surgery site. In severe cases of navicular apparatus degeneration, the DDFT may also be damaged. In the case of a neurectomy, the horse may not protect the foot as it previously had and overuse may lead to the rupture of the tendon. There is also a possibility of the nerve endings growing back and eventually providing sensation to the hoof again. However, when successful, a PD neurectomy can provide soundness for months to years.

Navicular syndrome is a frustrating disease to diagnose and treat, but advances in therapeutic shoeing have given practitioners more options and they continue to play a central role in the management of this condition. When selecting a shoe for a horse with palmar foot pain, it is important to have goals in mind for what you want to accomplish. Remember that this will be dictated not only by radiographs but also by the gross structure of the foot itself. Some shoes will accomplish multiple goals, whereas others may require modification to achieve the desired effect.

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The Authors have no conflicts of interest.

References
Shoeing the Chronic Laminitic Horse

Sammy Pittman, DVM

1. Introduction
Chronic laminitis is a commonly encountered disease process that can lead to long-term pain and suffering. Various definitions of chronic laminitis exist in the literature.1–9 Definitions are usually based on a timeframe from initial insult and range from 72 hours to several weeks (Fig. 1) after the initial onset of pain. The author identifies chronic laminitis as a lamellar structural failure (LSF) and is described by any case that has structural failure of the suspensory apparatus of the hoof capsule by any means. The focus of this paper is on the cases that present in the 4–8 weeks post-onset. A hierarchy of mechanical options, ranging from shoes that have a continuous roll from toe to heel (rock n roll, banana, self-adjusting palmar angle), static wedges, and deep flexor tenotomy, are selected based on a diagnostic process, including radiographs, history, physical examination, and venograms.

2. Materials and Methods
Multiple etiologies exist but all create a structural failure in some fashion to the lamellar bond. Systemic insults from dystocia, colitis, or grain overload appear to have progressive hoof pain without initial radiographic displacement, but progress to displacement after LSF occurs 4–6 weeks later. Many endocrinopathic-type laminitis cases already have radiographic displacement at the first onset of pain, secondary to the slow stretching of the lamellar bond under the influence of insulin.10–13 The author’s practice commonly receives laminitis cases that are 4–12 weeks post-onset, as traditional medical and minimal mechanical therapies have failed. A consistent timeline has been identified with regard to an acute-type case, involving a systemic insult, such as high fever, endotoxemia, dystocia, colitis, or grain overload.11 From the onset of pain/insult to structural failure with radiographic displacement very commonly ranges from 4–6 weeks. Major systemic insults can create significant structural failures and result in complete hoof capsule avulsion in a matter of days. However, this has been observed at a low frequency. The current highest number of cases of LSF seen in the author’s practice is a metabolic-initiated structural failure. Many times, a single trigger cannot be identified and is usually multifactorial. Obesity, diet, pituitary pars intermedia dysfunction, stress, and corticosteroid therapy are commonly identified factors.14 Any one of these reasons alone may not create an LSF but all work in combination, creating insulin dysregulation that can lead to significant damage to the lamellar bond. Consistent successful management of LSF must include a detailed investigation process, which directs the level of mechanical therapy needed relative to the level of damage. Medical management with regard to diet, analgesia, anti-inflammation, and medications to
manage pituitary pars intermedia dysfunction (PPID) and insulin dysregulation are important but considered complementary to the mechanical therapy.

Successful mechanical and medical management rely on an understanding of the pathologies at play and the level of structural damage that has already occurred. The severity of LSF is a large spectrum, and the appropriate level of mechanical therapy should match the level of failure.

Radiographic parameters, such as horn-lamellar zone (HL), coronary band extensor process distance (CE), sole depth (SD), and palmar/plantar angle (PA), are all important measurements that can be followed radiographically. The history and signalment can allude to possible causes and will guide the medical management. This is especially critical in cases associated with PPID and insulin dysregulation. A medical history often offers a timeline that can be compared with the growth of the hoof capsule. On average, each new growth ring is observed to be approximately 30 days apart. The sublamellar vessel system that suspends the digit between the DDFT and lamina within the hoof capsule. The deep flexor musculotendinous apparatus is largely responsible for determining whether the load is concentrated within toe or heel or is more evenly balanced. Consider two extreme examples. First, a neonate that has flexor contracture and is not applying any load to its heels, versus a foal born with flexor laxity in which no load is applied to the toe. The loads transmitted to the ground through the hoof are drastically different, with the contracture case loading the toe, versus the laxity case heavily loading the heel/bulbs. The major difference between these two scenarios is DDFT tension/length. The author believes the majority of horses are somewhere between these two extremes.

3. Venogram Evaluation

Venograms are simply a contrast-enhanced radiograph that highlight internal soft tissue components. This allows for a greater visualization of changes in normal anatomy as structural failure occurs. A representation of a healthy venogram is considered to be a horse holding 15 mm or greater of sole, even toe to heel growth, and 7–10 mm of wall growth every 30–45 days. When considering what is healthy or abnormal, one must consider the innate mechanical properties that exist for each case. Variations of normally accepted parameters may exist secondary to deviations in conformation, hoof type, and trimming/shoeing influence. Healthy feet are considered to have balanced mediolateral loads, DDFT suspension load, and load on support structures, such the frog and sole. However, a large majority of sound horses have mismatched feet, and obvious load discrepancies are revealed by various levels of hoof distortion.

A brief discussion of a nonlaminitic venogram (Fig. 2) appearance is as follows. Contrast will not fill up to the tourniquet when correctly applied but will stop just below. As the contrast courses distally, several venous branches arise, feeding the coronary band, terminal arch, digital cushion frog, and solar corium. In the lateral view, a uniform filling of contrast is noted over the coronary band. The coronary papillae are visualized protruding distally into the coronary crest at an angle similar to the face of P3 and direction of horn tubule growth. This is considered a very important growth center, as this region is responsible for wall growth. Contrast is visible filling the sublamellar vessels, which lies within 2–3 mm of the face of P3 in a continuous pattern. The sublamellar vessels are joined with vessels arising from the terminal arch as they course from the terminal arch to the periphery of P3.
The sublamellar venous plexus joins the solar plexus and the circumferential veins. Terminal and solar papillae are notable and are normally in the same plane as the dorsal surface of P3. The papillae are important, as they allow visualization of the growth centers for the production of a hard protective sole and horn. Typically, in hooves with a sole depth of 15 mm, approximately 10 mm will be contrast-filled solar corium and 5 mm of hard protective horn. Horses with a chronic thin sole will demonstrate very little to no papillae and have less than 2–3 mm of contrast-filled solar corium. One could hypothesize that this is why thin-soled horses appear to have minimal to no sole growth until sufficient mechanical solutions are applied to unload the compressed corium.

The dorsopalmar view is very similar to the lateral view but allows further visualization of the medial and lateral coronary venous plexus as well as the terminal arch. Oftentimes, the medial coronary plexus has decreased filling secondary to normal loading in the healthy foot, as the medial aspect of the hoof bears a greater load. In the author's experience, this is noted to improve in the unloaded and late lateral views in nonlaminitic cases.

Using external characteristics, radiographs and digital venograms in combination offer a vast amount of information relative to the level of structural damage, allowing for a more precise pairing of mechanics to structural damage. Early in the author's career, a similar level of mechanics was applied to every case, without regard for the large spectrum of damage unique to each individual case. The result is that not all cases experienced as much success because many had a higher level of damage, indicating a higher degree of management needed.

Comparative plain radiographs offer useful information concerning the degree of displacement of P3 and level of bone damage that has occurred; however, similar levels of radiographic boney displacement can have very different venogram characteristics. Venograms can highlight the internal anatomy, which may be displaced and compressed once the suspensory apparatus has begun to fail. It has proven to be very helpful as an adjunct tool to follow cases in the acute phase, as soft tissue and vascular changes are noted prior to structural collapse. Simply put, the greater the structural damage, the greater magnitude of displacement of tissue highlighted by the venogram and higher levels of compression are noted under the tip of P3, solar corium, and the sublamellar zone. As the level of damage identified increases, the level of mechanics prescribed must also increase. Ideally, the author performs plain film radiographs with radiopaque paste applied to the dorsal hoof wall from the coronary band to the tip of the toe, with a calibration tool in place for consistent measurements, as well as digital venograms on first examination.

The amount of sole depth, degree of pain, and evaluation of four crucial regions of the venogram will aid in deciding an initial mechanical therapy.

Fig. 2. Nonlaminitic venogram. A, Placement of inner tube tourniquet; B, catheter in lateral digital vein; C, coronary plexus and papilla; D, sublamellar zone; E, circumflex vessels and terminal papillae; and F, solar plexus and papillae.
These crucial regions of interest are the coronary plexus and papillae, sublamellar vessels, circumflex vessels, solar plexus and papillae, and the terminal arch.\(^7\) The successful use of the venogram requires a thorough understanding of soft tissue anatomy and function. Using the venogram to highlight the internal anatomy is helpful to identify changes in normal anatomy, secondary to a structural failure of the lamellar bond. As greater levels of structural failure occur, the greater level of soft tissue displacement and compression that can occur. For example, coronary, terminal, and solar papillae will deviate dorsoproximally from the plane of the face of P3 as structural failure increases, allowing P3 to displace. However, degrees of rotation are not consistently related to the degree of papillary displacement, as endocrinopathic cases often have moderate radiographic displacement with less than expected soft tissue displacement in the author’s experience. The author feels this is secondary to the insidious process in which hyperinsulinemia creates secondary lamellar hypertrophy versus an acute systemic insult that can occur after grain overload, endotoxemia, and dystocia. Typically, systemic insults have a greater level of venographic change compared with a similar level of bony displacement that has occurred from endocrinopathic cases.

Evaluating the level of bone resorption of the tip of the coffin bone (CB) can also be helpful in determining the level of damage. As the bone resorbs closer to the foramen of the terminal arch, the longer and/or greater level of damage is present and has a negative impact on prognosis. If the bone is visibly damaged, then one can assume the soft tissue is equally as affected. The corium is like any other tissue, it reaches a point of decreased functionality secondary to scarring and irreversible damage. Considering these boney and soft tissue evaluations, one can better inform the owner on prognosis and level of damage.

4. Prescribed Treatment Options

Mechanical Therapies

In the author’s opinion, loads within the hoof capsule are determined by limb conformation and DDFT suspension (i.e., clubfoot versus low heel, Fig. 3). For example, if a clubfoot experiences an LSF, those cases have a higher dorsal lamellar load to begin with and are therefore more likely to rotate. Horses with medial listing of P3 and diminished medial wall growth are more likely to sink medially. Whatever conformation and load deviations exist prior to LSF are considered highly suspect to be areas of increased damage in the face of a laminitic episode.

Mechanical therapies involve the application of varying degrees of load alteration through the DDFT. In the author’s practice, this may range from a slightly fully rockered 3–4-degree wedge shoe to a deep flexor tenotomy. Mechanical aggressiveness is dependent on damage assessment made through history, physical examination, radiographs, and venograms. Three major categories of mechanics currently exist in the author’s practice, varying degrees of fully rockered shoes, modified Ultimate Wedge\(^a\), or comparable mechanics that act as a static wedge around 20 dg, or a deep flexor tenotomy after derotational shoeing.

Once a mechanical option is selected, post-shoeing radiographs are taken to set a new baseline and confirm the mechanics have been changed as desired. Pre- and post-shoeing radiographs are taken at each recheck, every 4–8 weeks, depending on the case. The pre-shoeing radiograph determines the success of the mechanical application and provides a guideline for trimming and designing of the next option. Post-shoeing radiographs confirm that the plan has been successfully applied and sets a new baseline to compare with at the following examination. Many cases that are only 4–6 weeks post-initial onset undergo repeat venograms and radiographs as soon as 7–14 days to confirm progress or the lack thereof. In the author’s opinion, this allows for a recognition of a desired appropriate response, and, if needed, one can further increase the mechanical input to gain greater load change.

Significant increases in sole depth (5–10 mm) in 4 weeks are expected. If follow-up exams show a lack of appropriate response, then one must consider an option higher on the mechanical scale. As sole depth improves and the wall growth becomes even from toe to heel, then one can consider lowering the level of mechanics. The author prefers a gradual wean down of 3–5 degrees of the palmar angle after the sole depth has reached 20 mm. As long as even sole and wall growth is continually observed at each
recheck, then continued reduction of mechanics can occur, as new lamellar attachments are replaced. Typically, the author’s cases will remain in mild to moderate mechanics until an entirely new hoof has grown out. At any point, if the response is slowed or diminished, the horse is returned to a higher level of mechanics and reevaluated. This may identify lamellar structure that is not yet ready to antagonize the load of the DDFT.

**Fully Rockered Wedge Shoe (Fig. 4)**

Case characteristics that would lead the author to utilize this approach have a lesser degree of damage. Cases considered usually have at minimum 8–10 mm sole depth, mildly divergent growth rings from toe to heel, and lameness that is an obel lameness grade of 1–3/4. Venographic changes in these cases show minimally dorsoproximal displaced coronary; terminal, solar papillae; and circumflex vessels. In these cases, the coronary plexus is still very rounded, versus a more linear appearance from distal displacement. Solar papillae are present in the palmar aspect of the hoof but may become sparse toward the toe region. Minimal sublamellar vessel thickening with enhanced visualization of the axial veins of the dermal lamina will often be noted.

For application of these shoes, the heel and toe are trimmed in a rockered fashion. This allows for significant toe lever reduction and heel loading while leaving maximum depth under the CB. This load pattern allows for a reduction of load on the damaged lamina and compressed solar corium under the tip of the CB. The deepest portion of the rocker is placed under or behind the center of rotation of the coffin joint. At no time should the horse rock backward. Typically, shoe selection is a 4–6 degree wedge that is forged to fit the contour of the trim. Application can be directly glued with an Equilox type adhesive, nailed on, or glued with nails fit outside the wall.

**Modified Ultimate Wedge or Similar Static Wedging Applications**

This application provides a higher level of mechanical support and is used in cases with mid to higher scale damage. Most cases have a greater divergence of growth rings with the heel outgrowing the toe at least 3 to 1; a flat, thin sole that measures 4–8 mm; distally divergent HL zones; varying degrees of bone resorption but overall minimal; and an obel lameness grade 3–4/4. Venograms (Fig. 5) reveal a slight to moderate dorsoproximal displacement of coronary; terminal, and solar papillae but not quite horizontal. Straightening of the coronary plexus and varying degrees of a lack of coronary filling can be noted. Moderate dorsoproximal displacement of the circumflex vessels but not above the tip of the CB with contrast is still noted below the tip of the CB. Solar papillae are likely not visible except for in the heel region. A thickened sublamellar zone with a larger degree of axial veins of the dermal lamina is usually noted. These cases are often entering the septic phase secondary to weeks of vascular compression, creating avascular necrosis of P3. This ultimately leads to painful abscesses that often vent at the proximal coronary band or heel bulb.

For the application of this shoe, heels are trimmed very close to parallel with the wings of P3. Trimming the heel down and back in this manner and then wedging back up appears to offer more efficient heel loading in the author’s experience. If sufficient heel is present, this leaves enough base for the wedge to be applied without further modifications. However, when significant rotation has already occurred and the sole is thin, a toe pillar prop may be required to align the heel-loading surface with the wings of P3 (Fig. 6). This prevents any solar loading directly under the dorsal aspect of P3. A palmar angle that is approximately 20 degrees is typically sufficient to create a palpable decrease in tension to the

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Fig. 4. Case example demonstrating venogram on the first examination (A) and 4 weeks later (B), wearing a fully rockered wedge rail shoe. Note better filling of the sublamellar zone, less dorsoproximal folding of the circumflex vessels, and greater depth of the solar corium under tip of the CB.
However, further palmar angle enhancement with additional wedging or the addition of a rockered ground surface may be needed when higher levels of derotation are required. Lowering the mechanics to a high-scale rockered wedge rail shoe would be appropriate after a significant sole response (20 mm) has occurred. Gradual reduction in mechanics at each reset may be attempted as long as the response is appropriate (as described earlier).

One must consider the structural integrity of the lamellar bond. The author does not feel the lamellar bond is sufficient to accept full load until a complete hoof has regrown, and oftentimes, the goal is to maintain protective mechanics until that occurs. Follow-up venograms will show a return to a more normalized internal anatomy with less compression. On these normalized venograms, a normally oriented papilla, rounded coronary plexus, and less dorsoproximal folding of the circumflex network will be observed. If significant improvement does not occur and an increased sole depth is not achieved, then the next higher level of mechanical therapy to

Fig. 5. Example of a case where a modified ultimate wedge was selected and improved the venographic appearance from first exam (A) to second exam (B) 9 days later. Note better filling of the proximal sublamellar zone, less folding of the circumflex vessels, and better depth of corium under tip of the CB with better visualization of solar papillae under the tip of the CB.

Fig. 6. Example of building pillars to create a parallel line to wings of the CB.
Fig. 7. Example of a case where a deep flexor tenotomy was selected based on first exam venograms (A) 45 days after a grain overload. Note more linear coronary plexus with dorsoproximally displaced coronary papillae. Sublamellar zone is thickened with enhanced visualization of axial veins of the dermal lamina. Dorsoproximal displacement of the circumflex vessels above the tip of the CB. B, 30 days and C, 1-year post-tenotomy. Note improved coronary plexus shape with more normally placed papillae, improved circumflex anatomical restructuring, and better solar papillae visualization.
consider in the author’s opinion is a DDFT tenotomy following appropriate derotational shoeing.

**Deep Digital Flexor Tenotomy (Fig. 7)**

Cases that are selected for a DDF tenotomy will have failed to respond to high levels of mechanical shoeing or have severe enough venographic abnormalities to indicate the need for maximum deep flexor release and transfer of load to palmar hoof. Cases range from solar penetration to seemingly adequate sole depth, depending on how much sole depth was present at the time of insult. However, common venogram findings that suggest a tenotomy would be beneficial due to merely a greater level of soft tissue displacement than described above. A coronary plexus that appears vertical and linear in shape and often breaks in filling of contrast at the level of the proximal wall secondary to compression are observed. Coronary papillae, if present, may be horizontal or even working toward vertical orientation. Sublamellar zones are often broken in continuity, thickened from 2–3 mm to 7–8 mm, and are wider distally. The circumflex network is displaced at or above the tip of P3, and no solar or terminal papillae are noted. In the author’s experience, these cases respond best to a midcannon deep digital flexor tenotomy after appropriate derotational shoeing.21

A 5-degree aluminum rail shoe with a heel extension is glued on parallel to the wings of P3. This often requires only a small amount of heel to be trimmed in parallel fashion to the wings of P3 (Fig. 7, image B). The use of impression material to hold the shoe propped up off of the toe while the shoe being glued is helpful. Using Super Fast or a similar product to build a pillar on the shoe or foot to prop the shoe up is also a helpful technique. The shoe is glued on, then, typically, a modified Ultimate Wedge is taped over the derotation shoe to replace the lost wedge and prevent excessive pulling of the DDFT, creating increased rotational forces. This wedge is removed during surgery after the DDFT is severed to evaluate the surgical gap created. At minimum, the author repeats radiographs post-surgery as well as 4 weeks post-surgery.
Closely monitoring the palmar angle in the early stages prior to DDFT adhesion is important. Keeping a 3–5 palmar angle during the initial healing phase appears to offer the best long-term outcome. Once adhesion of the DDFT has occurred, around 4–6 weeks, manipulation of the palmar angle becomes more problematic. If the palmar angle becomes more positive, as it does in a clubfoot syndrome that has laminitis, the author will reduce the palmar angle as it climbs as long as when the heel is trimmed, it will touch the ground and a palpably soft DDFT is found. Once the tendon is adhered, then maintenance of a higher palmar angle is needed, as increasing the load in the DDFT will result in pulling on the tendon scar and potentially increasing load in the dorsal lamellar bone and solar corium under the tip of P3. It is equally important to prevent a negative angle, as excessive heel load can result in increased management long-term.

The prognosis of any case is determined by the soft tissue response to the mechanical and medical management. If a lack of response is noted, then the next higher level of mechanics should be considered. If you are at the top of the mechanical capabilities and the response is less than ideal, then euthanasia is considered the most humane approach. The author considers pain without progress as a guide for electing euthanasia. Other aspects to consider are the financial and emotional commitment the owner will need to allow for optimum success. Using a sound diagnostic and a monitoring protocol is helpful to aid clients in the decision-making process. If significant damage exists and the owners are not capable of that level of commitment, one can better inform the client and prevent unwarranted suffering for the patient.

5. Case Presentation

Case One: 3-Year-Old American Quarter Horse Association Gelding

History of an Allergic Dermatitis Starting June 2015

Treatment with oral prednisolone therapy was initiated on July 10th after topical treatments failed. Bilateral forelimb lameness was noted on July 24th, and radiographs were taken on the 31st that showed no signs of boney displacement. Repeat radiographs taken on August 9 indicated increases in CE, a loss of SD, and a distally divergent dorsal lamellar zone on the right front. The left front had more even displacement, with increased CE and an enlarged lamellar zone proximally and distally exhibiting a sinker type displacement (Fig. 8). The horse was treated with daily cold saltwater therapy and soft ride wedges from August 9th through September 6th. Radiographic displacement remained...
mostly static in this time, but very little, if any, SD or wall growth occurred during this time. Comfort level improved during saltwater therapy but pain began to increase once the horse returned home on September 6th. The horse was referred to the author's clinic for a second opinion on September 13th. The horse presented with a 2/4 obel grade lameness with mild digital pulses and positive hoof tester response across the sole bilaterally. See the timeline in Fig. 9.

Baseline lateral and dorsopalmar radiographs were taken and revealed the following parameters: left front (LF) CE 15.54 mm, proximal lamellar zone 7.92 mm, distal lamellar zone 9.22 mm, SD 7.3 mm, and palmar angle of 8.6 degrees; and right front (RF) CE 15.38 mm, proximal lamellar zone 6.76 mm, distal lamellar zone 11.43 mm, SD 10 mm, and palmar angle of 16 degrees. The left front lower profile hoof had a significant palpable ledge to the coronary band as well as the right front (RF) dorsal coronary band.

Venograms Performed Bilaterally (Fig. 10)

Venograms were performed in the modified ultimate, with no hoof trimming performed. The left front loaded lateral view exhibited a lack of filling of the coronary band in the quarter regions, with a slightly straightened coronary plexus and the coro-

Fig. 10. Left front top and right front lower on first examination 9.13. A, baseline radiographs; B, loaded dorsopalmar and lateral view; and C, unloaded lateral and palmarodorsal views. Note the medial and lateral coronary plexus of the right front in the unloaded PD shows improved filling; however, the left front lateral coronary plexus is still absent of contrast.
nary papillae were very slightly displaced dorsoproximally. The proximal sublamellar zone was broken in continuity and slightly thickened. A very slight dorsoproximal fold in the circumflex vessels was noted. No terminal or solar papillae were noted until the heel region, and the solar plexus was compressed to an extent that one cannot make out individual vessels. The DP view also showed a medial and lateral lack of contrast over the coronary band. A blunt stoppage of contrast was noted over the lateral coronary band that did not fully improve on the unloaded palmarodorsal view. This is a common finding when a medial or lateral sinking occurs. Oftentimes, a wall resection will be required in this area as this one did. The right front had similar yet more significant anatomical deviations and compression. The right front lateral loaded view showed a lack of filling of the coronary plexus and proximal sublamellar zone and slight folding of the circumflex network with a lack of recognizable terminal and solar papillae. Pooling of contrast outside of the vascular network was noted just below the tip of the CB. The DP view showed a lack of filling in medial coronary plexus. All areas that exhibited a lack of contrast improved on the unloaded lateral and PD.

Mechanical Treatment
Heels were trimmed parallel to the wings of the CB, leaving as much of the heel mass as possible. A small toe prop was applied to the toe pillar region of the modified ultimate on the more upright clubby

Fig. 11. Note more than doubled sole depth (red arrows) in 25 days while wearing the modified ultimate wedge.
foot that exhibited more rotational displacement. In the author’s opinion, reducing heel height, lengthening the base of support, and aligning the load zone with the wings offered a successful means of unloading the DDFT and efficiently moving load to the heels. This may allow compression of the heel while unloading compression under the tip of the CB and extraction forces in the damaged dorsal lamellar bond. The use of a two-part silicone rubber for solar support is applied in the palmar portion. The ultimate can be glued or bandaged. Repeat radiographs and venograms in 25 days showed significant improvement (Fig. 11). Patient comfort also improved, with a 1/4 obel lameness grade. Sole depth increased from 7.3 mm to 16 mm on the left front, with an increase from 7.7 mm to 14.5 mm on the right front. Venograms showed improved coronary plexus and sublamellar vessel filling, with improved vascular corium depth below the CB (Fig. 12A and B).

This shoeing was maintained and reset with radiographic control approximately every 30 days. Once the sole depth was at or above 20 mm, a reduction in static wedging by grinding a rockered profile to the bottom wedge of the ultimate was performed. This allows for more of a self-adjusting palmar angle versus a static. As sole depth continued to grow and wall growth continued to be even from toe to heel, a reduction in the mechanical support was attempted. At each recheck, radiographs confirmed good sole depth. At 4 months post-initial exam and 5 1/2 months after the first day of pain, the horse was in a rockered 6-degree aluminum wedge and being hand-walked daily (Fig. 13). This is maintained until the horse returns to active training, once a full hoof capsule has been replaced approximately 10–12 months post-initial insult.

Case Discussion
The information gained from this history, exam, and serial venographic and radiographic images allowed the author to select a mechanical solution that was successful. The response to mechanical therapy is

Fig. 12. A, Left front note improved coronary plexus (red circle) and continued lack of filling of the medial coronary plexus (blue arrow) in the loaded view of no significance. Improved solar corium depth (yellow circle). Also, note in the 10-8 image how the distal dorsal aspect of the CB pushed against the distal sublamellar zone. This indicates the properties of the mechanical therapy. B, Right front venograms with improved sublamellar zone filling (red circle) and more normalized circumflex anatomy (blue arrow).
very important and helps validate the therapy used. However, at any given time, if a lack of progress is noted, then repeat venograms and radiographs can be compared with previous images. If a regression or a lack of response is identified, then a higher level of mechanical support is needed. For example, if this case failed to quickly add sole depth and venograms exhibited a lack of improvement with regards to circumflex displacement, measurable vascular depth of the tip of the CB, return of visible solar papillae while wearing the modified ultimate, then a deep flexor tenotomy would be considered. A lack of response while wearing high-end mechanical therapy is an indication for deep flexor tenotomy in the author’s practice. A recovery is noted and a small degree of wedge is ground away to a lower palmar angle to allow more adjustability. As long as good comfort continues, as has occurred in this case, then continued reduction is performed. However, the author will not completely remove mechanical therapy that reduces load and resistance in the DDFT and, subsequently, the dorsal lamellar bond and solar corium under the dorsal aspect of the CB until a full hoof capsule has regrown. At that point, an increase in exercise with mostly walking is a recommended. A slow and gradual increase in workload every 1–2 weeks is suggested. This has been an effective effort to test the lamellar bond and its structural integrity.
6. Conclusion

It is important to note the same diagnostic and mechanical process has been helpful in the acute stages of laminitis prior to LSF. In the author’s opinion, a greater long-term success with less cases experiencing chronic complications is possible with early adequate intervention. Categorizing LSF into stages may be helpful, as cases that are 4–6 weeks from initial insult have better recoveries than cases that are months to years into the syndrome with significant bone resorption. Early mechanical intervention guided by radiographic and venographic input has offered greater levels of success in managing cases at high risk for developing LSF. Dystocia, colitis, placentitis, grain overload, contralimb lameness, and septicemia are all common scenarios that lead to LSF. Early recognition and mechanical therapy has proven helpful in the author’s experience.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes

8. Steward ML. How to construct and apply atraumatic therapeutic shoes to treat acute or chronic laminitis in the horse, 2018;331–346.

*Ultimate Wedge, Nanric, Lawrenceburg, KY 40342.
*Equilox adhesive, Equilox, Pine Island, MN 55963.
*Rail Shoe, Nanric, Lawrenceburg, KY 40342.
*Super Fast, Vettec, Oxnard, CA 93033.
Randomized Control Trial Comparing Flunixin Meglumine and Firocoxib in Equine Strangulating Obstruction

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Both flunixin meglumine and firocoxib are effective for the postoperative management of patients with small intestinal strangulating obstruction, and firocoxib is associated with reduced incidence of an elevated biomarker of endotoxemia, sCD14. Authors’ addresses: Department of Clinical Sciences, North Carolina State University College of Veterinary Medicine, Raleigh, NC 27606 (Ziegler, Freeman, Fogle, Burke, Davis, Blikslager); Department of Clinical Sciences, University of Pennsylvania School of Veterinary Medicine, Kennett Square, PA 19348 (Southwood); Department of Large Animal Clinical Sciences, Michigan State University College of Veterinary Medicine, East Lansing, MI 48824 (Cook); e-mail: alwelch@ncsu.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Small intestinal strangulating obstruction (SISO) is associated with endotoxemia and an increased risk of death. Nonsteroidal anti-inflammatory drugs (NSAIDs) treat endotoxemia by blocking cyclooxygenase (COX) 1 and COX-2. COX-1 is expressed constitutively and promotes gut barrier function, whereas COX-2 is induced in inflammation and contributes to signs of endotoxemia. In preclinical SISO models, barrier recovery occurred faster with COX-2 selective NSAIDs versus nonselective NSAIDs. We hypothesized that treatment of postsurgical SISO horses with firocoxib (COX-2 selective) would result in effective pain control and would reduce endotoxemia to a greater extent than flunixin meglumine (nonselective).

2. Materials and Methods
Fifty-six postoperative SISO patients were administered either flunixin meglumine (intravenous [IV] 1.1 mg/kg every 12 hours) or firocoxib (IV 0.3 mg/kg loading dose; IV 0.1mg/kg every 24 hours) in a blinded randomized control trial.

3. Results
No difference was observed in pain control or heart rate between groups (P=0.20, P=0.51, respectively). Both drugs inhibited the COX-2 prostanoid PGE2. COX-2 selectivity was confirmed by a greater inhibition of the COX-1 prostanoid TXB2 in the flunixin meglumine group (P=0.014). There was a 3.23-fold increased risk (P=0.044) of elevated plasma sCD14,
a validated equine biomarker of endotoxemia in the flunixin meglumine group. Both groups had a similar prevalence of clinical endotoxemia signs (P=0.30) and only a 1.4-fold relative risk of non-survival in the flunixin meglumine group (P=0.54).

4. Discussion
In SISO patients, flunixin meglumine or firocoxib effectively controls postoperative pain and heart rate, but firocoxib is associated with a reduced risk of elevated sCD14.

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
How to Remove Cystic Calculi in the Standing Sedated Horse Using a Laparoscopic Retrieval Pouch

Scott A. Katzman, DVM, DACVS-LA

1. Introduction

Urolithiasis remains an infrequently diagnosed condition in horses, constituting 0.11% of equine admissions to university veterinary teaching hospitals in the United States over a 19-year period, with 59.7% involving cystic calculi.

The most common clinical sign is hematuria, which is often exacerbated by exercise. Additional clinical signs include tenesmus, incontinence, dysuria, stranguria, pollakiuria, urine scald, and less commonly, weight loss.

Uroliths in horses are primarily composed of calcium carbonate crystals, with a smaller proportion of calculi containing magnesium ammonium phosphate, calcium oxalate, and calcium sulfate in addition to calcium carbonate. Uroliths are classified as either type 1 or type 2, with type 1 accounting for approximately 90% of uroliths in horses. Type 1 calculi are comprised of calcium carbonate, typically have a spiculated surface with a yellow to yellow-green color, and are relatively easily fragmented. In contrast, type 2 uroliths contain phosphate in addition to calcium carbonate, have a relatively smooth surface with a grayish-white color, and are more resistant to fragmentation.

Diagnosis of cystic calculi is typically made on the basis of clinical signs and results of palpation per rectum, transrectal ultrasonography, and transurethral endoscopic examination of the urinary bladder.

Several methods have been described for the removal of cystic calculi from horses including laparocystotomy, laparoscopic techniques, transurethral removal, pararectal cystotomy, and removal through a perineal urethrotomy (PU) (males only). Currently, laparocystotomy is considered the treatment of choice, given that it avoids the difficulties often encountered during removal from standing horses.

Techniques reported for removal of cystic calculi from standing sedated horses include manual crushing, fragmentation with a mallet and osteotome, pulsed-dye laser, holmium:yttrium-aluminum-garnet (Ho:YAG) laser, electrohydraulic shockwave, or ballistic shockwave, followed by fragment removal.

Intraoperative complications associated with removal of cystic calculi from standing horses include...
rectal tear, perforation of the urinary bladder or urethra, unsuccessful attempts to fragment calculi, and an inability to remove all fragments from the bladder. Reported postoperative complications include peritonitis, fever and urethritis, retained fragments causing urethral obstruction, urethral stricture, and recurrence.

In light of the difficulties often encountered while attempting successful, complete removal of cystic calculi in the standing sedated horse, and the many complications which can be encountered, the following technique was developed. A laparoscopic specimen retrieval pouch is utilized to contain and stabilize cystic calculi during fragmentation and facilitate safe removal of calculi. Further, the pouch protects the urinary bladder and urethra from iatrogenic trauma during removal of intact calculi or following fragmentation of calculi.

2. Materials and Methods
For horses diagnosed with cystic calculi, a thorough physical examination, followed by ultrasonographic and endoscopic imaging should be performed. Ultrasonographic examination should include transcutaneous examination of the left and right kidneys, followed by transrectal examination of the urinary bladder, left kidney, and left and right ureters to determine the approximate size of the cystolith, as well as identify other uroliths or gross abnormalities affecting the urinary tract. Preoperative serum biochemical analysis (CBC) should also be performed, as additional abnormalities identified during physical examination, diagnostic imaging or hematologic evaluation may guide treatment and have a substantial impact on prognosis.

In preparation for surgery, an intravenous jugular catheter should be placed, and horses administered procaine penicillin G (22,000 U/kg IM), gentamicin sulfate (6.6 mg/kg IV), and flunixin meglumine (1.1 mg/kg IV), and tetanus toxoid. Horses are restrained in standing stocks and a loading dose of detomidine hydrochloride (0.02–0.05 mg/kg/h) can be given to further relax the bladder and urethra. Sterile lubricating jelly with 2% lidocaine hydrochloride solution is infused into the urinary bladder by use of a 60-mL syringe and mare insemination pipette, and traction can be placed on the purse string to exteriorize the mouth of the pouch.

Once partial exteriorization is achieved, attempts can be made to remove the calculus intact by placing traction on the pouch (Fig. 1). For horses in which this is not possible, lithotripsy of the calculus can be pursued. The author prefers pneumatic radial shockwave lithotripsy or manual calculus crushing with Knowles uterine forceps through the opening of the pouch. Caudal traction placed on the edges of the pouch by an assistant is essential to stabilize the calculus at the trigone of the urinary bladder (Fig. 2). Periodic lavage of the lumen of the pouch flushes out dislodged fragments. Lithotripsy is continued until the calculus is reduced in size to a manageable fragment that can be removed by placement of a self-retaining Weitlaner retractor helps to facilitate visualization. The incision is continued through the corpus spongiosum penis to expose the caudal aspect of the urethra, and a longitudinal incision made directly over the indwelling urinary catheter into the urethral lumen. Now the urinary catheter can be removed and a flexible 1-meter endoscope can be directed through the PU in geldings or transurethrally in mares to allow visualization of the urinary bladder.

An evaluation of the urinary bladder should commence, and once the calculus has been observed, the laparoscopic specimen retrieval pouch can be introduced alongside the endoscope, and the pouch deployed. The calculus is manipulated into the pouch by sweeping the mouth of the pouch down one side of the bladder, along the floor to contact the calculus and up the contralateral wall which causes the calculus to roll into the pouch. This maneuver may take a few attempts to be successful. The pouch is closed by placing traction on the purse string attached to the pouch, and the introducer is discarded. Before attempts are made to manipulate the calculus within the pouch, N-butylscopolammonium bromide (0.3 mg/kg IV) can be given to further relax the bladder and urethra. Sterile lubricating jelly with 2% lidocaine solution is infused into the urinary bladder by use of a 60-mL syringe and mare insemination pipette, and traction can be placed on the purse string to exteriorize the mouth of the pouch.

Fig. 1. Laparoscopic retrieval pouch introducer and detached polyurethane retrieval pouch displaying a cystic calculus successfully removed intact. The depth of pouch allows for exteriorization of its opening following containment of calculi, facilitates manipulation, stabilization, and when necessary, fragmentation of calculi.
point that it can be easily and atraumatically removed from the urinary bladder within the retrieval pouch (Fig. 3). Following calculus removal, the endoscope is again inserted into the urinary bladder to visually assess its integrity and to ensure no additional calculi or fragments remain. At the completion of the procedure, the urinary bladder can be lavaged with physiologic saline (0.9% NaCl). The PU is left to heal by second intention.

Oral administration of antimicrobials and non-steroidal anti-inflammatory drugs (NSAIDs) are continued for 10 to 14 days postoperatively.

3. Results

Recently, the author’s practice reported on eight initial cases (five geldings and three mares) in which this technique was employed. Horses ranged in age from 10 to 24 years (mean ± SD, 17.7 ± 4.8 years) and were adult horses with weights ranging from 430 to 586 kg (mean ± SD, 491 ± 55.2 kg). Horses were presented for hematuria after exercise (three geldings and three mares), signs of abdominal discomfort (1 gelding), and pollakiuria (1 gelding). All horses underwent full physical, ultrasonographic urinary tract, and cystoscopic examinations.

Cystoscopic examination confirmed the presence of a solitary spiculated yellow-green calculus in 7 horses and 2 smooth gray calculi in one gelding. Varying degrees of mucosal hyperemia and petechiation indicative of cystitis were detected in all horses.

Calculi ranged in size from 4.6 to 7 cm in diameter (mean, 6.0 ± 0.9 cm). All horses had a preoperative CBC and serum biochemical analysis performed. For one horse, abnormalities suggestive of chronic renal insufficiency were identified evidenced by marked increases in blood urea nitrogen and creatinine concentrations.

Duration of surgery ranged from 40 to 255 minutes (mean, 125 ± 63 minutes). For three horses (one gelding and two mares), it was possible to remove the calculus intact. For the other five horses, fragmentation of the calculus was required to facilitate removal. Each laparoscopic retrieval pouch was examined for damage following calculus extraction, with none noted regardless of manipulations or removal method used. Calculi were removed completely from all horses without any fragments remaining in the urinary bladder. No evidence of iatrogenic injury to the bladder was identified in any horse, and no postoperative complications associated with the procedure were encountered, regardless of technique employed to facilitate calculus removal. To date, the author’s practice has utilized this technique in a total of 18 horses, and it has become the treatment of choice for standing removal of cystic calculi at our institution.
4. Discussion

The laparoscopic specimen retrieval pouch device used to remove cystic calculi from the horses in the present report consists of a 15-mm-diameter, 34.5-cm-long introducer and a 12.7-cm-diameter, 22.9-cm-deep polyurethane pouch (Fig. 4). The pouch is attached to a flexible metal ring, which maintains it in an open position without the aid of additional instruments. When the pouch is deployed, a working length of 47.2 cm is achieved. The long working length, coupled with the diameter and depth of the pouch, allows for easy manipulation of large cystic calculi into the pouch. Pulling on the purse string closes the pouch and detaches it from the metal ring. Because of the depth of the pouch, its opening can be exteriorized through a PU site in geldings or transurethrally in mares by placing traction on the purse string. In situations in which fragmentation of the calculus was necessary in the present study, caudal traction on the opening of the pouch allowed for direct visualization of the calculus, provided adequate stabilization necessary to facilitate fragmentation, and obviated the risk of rectal tear, urinary bladder or urethral perforation, or incomplete removal associated with other previously described methods for removal of cystic calculi from standing horses.

As mentioned, several types of lithotripsy have been described to facilitate removal of cystic calculi. The author prefers pneumatic shockwave lithotripsy, however, because containment and stabilization of cystic calculi is consistently achieved with the laparoscopic retrieval pouch and it appears complications associated with this technique are minimal, its use should be compatible with other methods of lithotripsy.

Although standing removal of cystic calculi has been reported to be associated with a high incidence of intra- and postoperative complications, none have been encountered while using this technique in the 18 horses for which it has been employed, and none reported by owners following discharge from the hospital. Additionally, the protection the laparoscopic retrieval pouch affords the urinary bladder and urethra as calculi are manipulated or fragmented within the pouch and subsequently removed cannot be overstated. This is considered one of the major benefits associated with this technique.

Although laparocystotomy is considered the treatment of choice for removal of cystic calculi,1–4,6,10 disadvantages include the need for general anesthesia, difficulty maintaining the urinary bladder in an exteriorized position, risk of incisional infection and dehiscence, and greater cost and longer postoperative convalescence time than for removal from standing horses. However, all cases reported here were adult full-size horses and use of the laparoscopic retrieval pouch has not been evaluated in ponies or miniature breeds. Because of the smaller size and reduced access to the bladder through a PU or transurethrally in these smaller breeds, this technique may not be feasible and may necessitate laparocystotomy.

Use of the laparoscopic specimen retrieval pouch is a safe, rapid method for removal of cystic calculi from standing sedated horses regardless of whether intact removal was possible, or fragmentation was necessary. The dimensions and durability of the pouch rendered it an effective means of protecting the urinary bladder and urethra of all horses from iatrogenic trauma as well as containment of debris when fragmentation was necessary to facilitate calculus removal. Its use appears to reduce the incidence of intraoperative complications, postoperative morbidity rates, and risk of calculus recurrence or subsequent urinary tract obstruction associated with incomplete calculus removal.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes


*Stallion urinary catheter, Jorgensen Labs, Loveland, CO 80538.

FUjinon EVE 400 Series, Fujinon, Wayne, NJ 07470.

Endo catch II specimen retrieval pouch, Covidien, New Haven, CT 06511.

Vet One OB lube, MWI Veterinary Supply, Boise, ID 83705.

Dualith Vet, Storz Medical, Tägerwilen, Switzerland.

Sharp & Smith, Chicago, IL.
Review of Repeat Celiotomy Following Small Intestinal Strangulation: Decision Guidelines, Intraoperative Findings, and Outcomes

Anje G. Bauck, DVM, DACVS-LA*; and David E. Freeman, MVB, MRCVS, PhD, DACVS

Early repeat celiotomy (within 48 hours of onset of clinical signs) can contribute to more favorable and more humane results than reported previously, with elimination of postoperative reflux and/or postoperative colic. Authors’ address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32610; e-mail: baucka@ufl.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Although repeat celiotomy is rarely required after colic surgery in the horse, it can place considerable stress on the owner, both emotionally and financially. Owners become concerned about the suffering and pain inflicted on the horse by a second surgery, and their negative feelings are supported by the outcomes from a recent study. Cost is also an important issue and must be balanced against potential benefits that are not always evident. If confronted with this decision, it is not unusual for owners to seek guidance from their own veterinarian, particularly the referring veterinarian, placing this person in a difficult position. Therefore, the purpose of this review is to identify positive experiences with repeat celiotomy that should help with the decision-making process. With this information, referring veterinarians can guide their clients with a more informed approach to a complicated and expensive procedure.

Repeat celiotomy is required in 12%–27% of horses after small intestinal surgery, which accounts for up to 88% of all repeat celiotomies. Short-term survival after a repeat celiotomy ranges from 27%–80%, with long-term survival from 12%–40%. A review of recent data suggests that survival rates after repeat celiotomy have not improved over a 10-year period. The procedure most likely to require repeat celiotomy is jejunocecostomy, which is also the surgery with the lowest overall survival rate. Unfortunately, horses that had a jejunocecostomy are the least likely to receive a repeat celiotomy, largely because of a perceived poor prognosis for a second surgery after this procedure.

Possible explanations for a poor prognosis for repeat celiotomy include the lack of specific guidelines in the literature for when repeat celiotomy is required, failure of most studies to examine repeat celiotomy by segment or procedure, the high cost of colic surgery in general and for repeat celiotomy specifically, and a tendency by most veterinarians to overrate the true role of postoperative ileus (POI) versus a physical obstruction to explain failure of the first surgery. The purpose of this review is to examine more recent publications that address...
these concerns and have revealed improved approaches to management of cases that might require repeat celiotomy. From this review, important findings have emerged, such as improved guidelines for selecting repeat celiotomy, discovery of lesions that can be overlooked, effective surgical treatment of intestinal complications that led to repeat celiotomy, and improved short- and long-term survival rates compared with previous reports. This discussion does not relate to large intestinal surgery, because repeat celiotomy is rarely required for this surgery during the same hospitalization period. Jejunoileostomy is rarely used in the authors’ hospital, so there is no data on this procedure, although it is associated with a high rate of repeat celiotomy.

2. Guidelines for Repeat Celiotomy

Selection criteria for repeat celiotomy have not been well described in the literature and have not been defined relative to segment of intestine and procedure performed. Another reason for lack of guidelines is the failure of most studies to distinguish on clinical or laboratory findings the difference between POR caused by a physical obstruction or POI. Part of the reason for this failure is that there are no distinguishing features and true POI might be less common in horses than most reports would suggest. The other reason is the tendency to group all intestinal segments together in most large retrospective studies, including incisional complications with intra-abdominal complications. The guidelines used for horses that had surgery for small intestinal disease were predominantly based on the following: horses with POR, postoperative colic (POC), or both that do not improve within the first 48 hours after onset of clinical signs are candidates for repeat celiotomy. This differs from previous reports that relate time of repeat celiotomy to the end of the first surgery, not to the onset of clinical signs, which the authors regard as a far more clinically relevant timeline. The definition of POR used in this review was any reflux after surgery and the inability to eat small handfuls of hay without reflux.

3. Client and Referring Veterinarian Discussions

In this hospital, owners and referring veterinarians are informed that repeat celiotomy might be required as soon as complications develop. Although this might seem premature, it is better than surprising them with this option when days of fruitless medical therapy have passed and all financial resources have been drained. It also prevents the delay in decision-making that might lead to a poor outcome through adhesions and a decline in the horse’s metabolic status. A successful outcome after repeat celiotomy can allow the horse to start eating, shorten the interval for fluid therapy, and shorten its hospital stay.

In a recent study, repeat celiotomy was performed between 11–120 hours after the first surgery, the upper end of the range produced by an owner that requested prolonged medical treatment before repeat celiotomy. This horse was euthanized under anesthesia because of extensive adhesions, secondary to prolonged obstruction by a shortened mesentery that kinked the anastomosis. The median duration of post-operative reflux (POR), POC, or both in this study was only 16.5 hours before repeat celiotomy. In horses with POC, the severity of pain shortened the duration between first and second surgery significantly, evidence that this complication can be severe enough to hasten the decision to do a repeat celiotomy.

4. Intraoperative Findings

In horses that had a small intestinal strangulation treated by resection and jejunojejunostomy at the first surgery, findings at second surgery included inadvertent anastomotic rotation by the surgeon, impacted anastomosis, ischemic mucosa at the anastomosis (Figs. 1A and 1B), leaking anastomosis, and mechanical kinking of the anastomosis caused by an excessively shortened mesentery (Fig. 2).

In horses that had a jejunocecostomy at the first surgery, findings at repeat celiotomy included impacted anastomosis (Fig. 3), hemorrhage from the ileal stump, continued necrosis of the ileum or adjacent cecum, small intestinal volvulus at the stoma, right dorsal displacement of the large colon, cecal distention, and serositis with or without fibrinous adhesions attributed to leakage because the anastomotic staple lines were not oversewn.

Lesions at repeat celiotomy apparently not related to an anastomosis included adhesions, small colon wrapped around the small intestine, jejunal infarct, impacted gastric antrum, small intestinal distension, jejunal stricture, a missed lesion, and small intestinal volvulus. No horse had evidence of diffuse peritonitis at the second surgery, although some had serositis and fibrin in the area immediately adjacent to those anastomoses suspected of leaking.

5. Corrective Surgical Procedures

In horses originally treated by jejunojejunostomy in a recent study, the majority of them (9/11; 82%) were treated at the repeat celiotomy by revision of the original anastomosis and manual decompression of distended small intestine. For horses with strangulating small intestinal lesions that did not have a resection at the first surgery, 4/8 were treated with resection and anastomosis at repeat celiotomy, with the rest undergoing simple manual decompression. In one horse that had two repeat celiotomies, POR ceased after the second one, which involved removal of dehydrated contents from the large colon through an enterotomy and manual decompression of the small intestine.
In horses that had a jejunocecostomy initially, treatment at the second surgery is more complicated than with jejunojejunostomy, largely because there are fewer options if the anastomosis needs to be revised. With impacted anastomosis, a distal jejunal enterotomy is made oral to the anastomosis to remove feed material from the impaction. After resolution of the impaction, the jejunum and cecum are opened at the proximal commissure of the original anastomosis and in continuity with it to enlarge the stoma by 3–4 cm, or as needed to produce an 8–10-cm opening (Figs. 4A and 4B). If the jejuno-cecal anastomosis has developed ischemia in the jejunal segment,3,16 the jejunum can be resected back to healthy tissue and the remaining incision in the cecum can be used for a handsewn anastomosis. If needed, the cecal defect can be closed to match its size with the surgeon’s goal for the stoma size.3 If these steps fail, other options include creating a new anastomosis between the dorsal and lateral band of the cecum20 after closing the original jejunocecostomy site. Another alternative is to perform a jejunocolostomy. In horses with a necrotic ileal stump, attempts are made to resect the stump more distally to healthy tissue using a TA-90 stapling device.16

6. Postoperative Outcomes
In a recent study, one or two repeat celiotomies eliminated POR after the first surgery in 13/16
horses (81%) with this complication. After the second surgery, POR was recorded for brief intervals in 21% of all horses, which is considerably less than the 60% reported by others. A repeat celiotomy eliminated POC in all horses that developed this complication after the first surgery and were allowed to recover from anesthesia. This finding provides evidence that POC after small intestinal surgery is a strong indicator for repeat celiotomy.

In one horse in which a jejunocecostomy had been performed approximately 10 years previously, a segment of small intestine was found strangulated through an incomplete mesenteric closure at the previous surgery. The strangulated segment was resected and a jejunocecostomy was created between the dorsal and lateral bands. At 48 hours following surgery, the horse began to reflux and a repeat celiotomy was performed. The cecum at the original anastomosis site was necrotic. Attempts to invert the necrotic segment into the cecum failed and the horse was euthanized following surgery. This case illustrates the challenge with strangulation of a jejunocecostomy months to years after it was originally made. The ischemia on the cecum was probably brought about by a transfer in blood supply that converted the last jejunal artery to become a major arterial supply to the cecum and the original anastomosis. Loss of this artery by the strangulating lesion years later placed the horse at risk of a cecal infarct that was not readily corrected by repeat celiotomy.

In horses that had repeat celiotomy for a strangulating lesion in a recent study, 3 horses with jejunojejunostomy were euthanized under anesthesia at the second surgery for humane and financial reasons and 19 horses were recovered from general anesthesia. Of the 3 euthanized horses, one had anastomotic rotation and strangulation through surgical error, another had small intestinal volvulus (same lesion as at first surgery) with necrosis of all remaining small intestine, and the third had extensive jejunal adhesions. The last horse had an interval of 5 days between the first and second surgeries, longest of all in the study. These cases illustrate the value of repeat celiotomy to terminate hopeless cases rather than submitting them to protracted and costly medical treatment.

In one study, incisional infections developed in 56% of horses that had repeat celiotomy compared with 7% that had a single surgery. In a more recent study, incisional infections were diagnosed in 13/17 horses operated on both times through the same midline incision. A total of 4/13 (31%) horses with incisional infections developed hernias, 3 of which were repaired. Other complications recorded included jugular thrombophlebitis in 1 horse and colitis and fever in another case. However, all 19 horses (86% of original 22) were discharged from the hospital despite these complications.

7. Survival Rates
In a recent study, all 19 horses that were allowed to recover from repeat celiotomy survived, to produce a 100% survival rate if the first surgery was treatment of jejunal strangulation by jejunojejunostomy or no resection. The median survival time was 90 months for the horses that did survive to anesthetic recovery, indicating an excellent long-term survival.
A survival rate of 71% has been reported for repeat celiotomy in the authors’ hospital in horses that had a jejunoccecostomy at the first surgery, and many of these horses had excellent long-term survival rates.16

8. Discussion
In the recent literature, the prognosis reported for survival after repeat celiotomy is highly variable. Dunkel et al.1 and Findley et al.15 reported a 40% and 45% survival to discharge for repeat celiotomy, respectively, compared with 100% survival to discharge in horses recovered from anesthesia reported by Bauck et al.18 The main differences between these studies1,15 are the types of lesions and the timing of repeat celiotomy. Dunkel et al.1 and Findley et al.15 included large intestinal lesions whereas Bauck et al.18 only included jejunal strangulations. Furthermore, Bauck et al.18 recommended a much shorter interval between the original surgery and repeat celiotomy, compared with the other two studies. A critical observation that has emerged from the author’s personal experiences is the greater importance of physical lesions (anastomotic obstruction, perianastomotic ischemia, and technical errors) in POR versus the role of POI. When this fact is recognized, a different approach can be taken to repeat celiotomy that the authors consider critical to the outcome (see Conclusions below).

The complete elimination of POR in 81% of horses by repeat celiotomy is superior to POR reduction by 25% of horses in one study,1 and the prevalence of POI in 62% of horses after repeat celiotomy in another study.12 Because POR rates as high as 70% have been reported after the first small intestinal surgery in horses,21,22 the second surgery should have increased this complication in these horses. Instead, of the 19 horses that recovered from surgery, 4 (21%) had POR, which is considerably lower than previous rates after a single surgery.21,22

The timing of repeat celiotomy has been previously documented as the interval between the first and second surgeries.1,12 In the study by Bauck et al.18 the interval between onset of signs and repeat celiotomy was seen as a more meaningful measure of severity of a complication. Authors of that study speculated that the favorable results they obtained were related to a general policy in that hospital to discuss repeat celiotomy with owners as soon as a problem is identified, facilitating a quick return to surgery. Early repeat celiotomy should be considered as a strategy to reduce suffering, harmful effects of protracted intestinal distention, and risks of adhesions from prolonged contact between amotile inflamed serosal surfaces. Although the cumulative inflammatory effects of intestinal manipulation imposed by a repeat celiotomy are undesirable, they do not seem to cause or exacerbate POR and should not be considered as an argument against repeat celiotomy in suitable candidates. The major concern with repeat celiotomy is expense, incisional infection, and hernia formation, and future efforts should be directed at preventing these complications. The impact of hernia formation on use of the horse could be considerable, especially from the owner’s perspective, and needs to be addressed in the decision-making process.

A variety of lesions at repeat celiotomy were encountered in the cases reported here than have been previously described in the veterinary literature. An important conclusion from these findings should be the prevalence of lesions caused by mechanical and technical problems with the anastomosis rather than nonspecific POI. This highlights the importance of meticulous surgical technique in performing either a jejunoojejunostomy or jejunoccecostomy. The authors favor a single layer, interrupted Lembert/appositional pattern with minimal inversion to perform a jejunal anastomosis, because this pattern yielded a 0% rate of POR23 compared with approximately 60% with other reported patterns.5,21 It also had a short-term survival rate >90%, with no deaths related to the anastomosis.23 Because of these positive experiences, we would regard POR or PO after this anastomosis to be a deviation from the expected postoperative response and a strong indicator of the need for a repeat celiotomy. Also, if a jejunoojejunostomy is indicated at the repeat celiotomy, the same minimal inversion single layer Lembert/appositional pattern23 is the anastomosis of choice.

The authors recommend revising the original anastomosis unless there is a clear indication that another lesion in the abdomen is responsible for signs of POR or PO. In the authors’ experience, the anastomosis can develop mucosal ischemia immediately proximal or distal to the anastomosis, and, because these changes were not evident on the serosal surface, they would have gone undetected without resection. Furthermore, the degree of mucosal cuffing contributing to anastomotic impositions can be underestimated unless an anastomosis is repeated. Others have reported a lower rate of anastomotic revision,1 which might have adversely affected their results. Although jejunoccecostomy can pose a technical challenge for repeat celiotomy, the authors believe that positive results can be obtained from a second surgery in horses that have undergone this procedure.16

9. Conclusions

- Early repeat celiotomy should be considered in any horse with signs of POR, PO, or both in which a small intestinal strangulation was identified at the original surgery and the response to postoperative treatment is unsatisfactory.
- The goal is to perform a repeat celiotomy if indicated within 48 hours after the onset of clinical signs.
The discussion with the owner about the need for a repeat celiotomy should start as soon as complications (POR, POC) develop to avoid surprising them with this issue or denying them time to consider it. 

If another jejunojejunostomy is indicated, this should be a single layer Lembert/appositional pattern with minimal inversion.23 If a jejunocecostomy is needed, a technique associated with a low rate of reflux is also recommended.16 If repeat celiotomy reveals an untreatable problem, euthanasia spares the horse from further suffering and the owner is spared the expense of continued and ineffective medical treatment.

The most experienced surgeon on the team should be consulted on the need for a second celiotomy and be involved in the surgery, if possible.

Surgeons can experience a considerable mental block to repeat celiotomy. This must be overcome, even if faced with the risk of exposing a surgical error.

The negative attitude toward effects of repeat celiotomy and survival should be tempered with the understanding that most horses that survive a second surgery would have died without it.

The benefits of repeat celiotomy can outweigh the risks and disadvantages in most cases.

Acknowledgments

Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.

References and Footnote


Predictive Value of Plasma and Peritoneal Creatine Kinase in Horses with Ischemic Intestinal Lesions

Isabelle Kilcoyne, MVB, DACVS*; Jorge E. Nieto, MVZ, PhD, DACVS, DACVSMR; and Julie E. Dechant, DVM, MS, DACVS, DACVECC

Use of creatine kinase measurement in peritoneal fluid should be as an adjunct to clinical case presentation and may help provide earlier diagnosis, quicker definitive treatment and reduced morbidity and mortality in horses presenting with strangulating intestinal lesions. Authors’ address: Department of Surgical and Radiological Sciences, School of Veterinary Medicine, University of California–Davis, CA 95616; e-mail: isabellekilcoyne@hotmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Early and accurate recognition of an ischemic lesion is essential to expedite surgical intervention to decrease the incidence of complications and increase patient survival in horses presenting with colic. The purpose of this study was to determine if peritoneal creatine kinase (CK) would be a sensitive indicator of intestinal ischemia compared with peritoneal lactate.

2. Materials and Methods
Creatine kinase activity was determined in peritoneal fluid and plasma of 10 healthy horses and 61 horses presenting for colic, including 40 horses with nonstrangulating lesions and 21 horses with strangulating lesions. Information on other blood and peritoneal fluid variables, signalment, results from the physical examination, outcome, need for surgery, and lesion location and type were retrieved from the medical records of horses presenting for colic.

3. Results
A peritoneal CK cut off level of 11.5 IU/L for predicting intestinal ischemia yielded a sensitivity of 95.5% and specificity of 82.1%. A peritoneal lactate cut off level of 3.75 mmol/l yielded a sensitivity of 81.8% and specificity of 92.1%.

4. Discussion
Results of this study suggest that strangulating lesions of the intestine can produce significant elevations in peritoneal CK values and measurement of peritoneal creatine kinase is a sensitive indicator of intestinal ischemia in horses presenting with colic.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
Online Survey: Evisceration Post Equine Castration with Evaluation of Independent Variables of Method, Position, and Breed

John C. Haffner, DVM*; Gema Vidal, DVM, MPVM; and Eric W. Davis, DVM, MS, DACVS, DACVIM

When considered together, all methods of castration have a low incidence of evisceration (0.20%).

1. Introduction
The most serious complication of equine castration is death/euthanasia due to evisceration. Differences in technique include method of removal of testes and position of the horse during surgery, i.e., standing versus recumbent. It is also thought that some breeds are more predisposed to evisceration than others. The objective of this survey was to try to determine the odds ratio of evisceration after castration considering breed, method (emasculation or twisting), and position (recumbent or standing).

2. Materials and Methods
Online surveys of members of the American Association of Equine Practitioners general discussion group and the Equine Clinician’s Network (ECN) was conducted in May 2017 concerning post castration evisceration/eventration. Information sought included 1) The percentage of each of the breeds castrated; 2) how many of each breed eviscerated, indicate which method was used and whether the horse was standing or recumbent; and 3) what percent of each method was used for castration? The methods included emasculation, twisting, and ligature. Breeds selection in the survey was taken from the United States Department of Agriculture (USDA) top 9 US breed registries plus “Draft” and “Other breeds.” With the evisceration as the outcome of interest, three different logistic regression models were fitted, one to compute the odds ratio based on breed, one to compute the odds ratio based on castration method, and a third one to compute the odds ratio based on horse posture while castrating. There was no significant clustering effect by practitioner. A confidence level of...
.05 was used for all statistical analyses. All data analyses were performed with open-source statistical software R.2

3. Results
One hundred forty-four valid responses were collected representing 41,664 castrations performed in the previous 10 years with 82 eviscerations for an overall rate of 0.20%. The total number of valid records for breed, position, and technique varied due to incomplete responses on some records. There were 133 valid responses considered in the breed analysis. The breeds included in the survey are as follows: American Quarter Horse, American Paint Horse, Thoroughbred, Arabian, Appaloosa, Standardbred, American Saddlebred, Morgan and Tennessee Walking Horse, Draft, and “Other” consisting of Donkey, Mule, Hackney, Warmblood, Andalusian and Paso type.

The results considering breed are shown in Table 1. Comparisons of individual breeds to all breeds are shown in Table 2. The results by position are shown in Table 3. The results by method are shown in Table 4. Questions from the survey are listed in Appendix 1.

4. Discussion
Evisceration is an infrequent but serious complication of one of the most common procedures in equine practice. It was not determined by this study whether eviscerations occurred when the practitioners was less experienced with the techniques or later in their career. In future studies experience should be evaluated. This survey reflects similar results reported by Moll et al1 for evisceration after castration. In that study, 47 of 23,339 (0.20%) horses suffered eversionment. This is lower than the 27 of 568 (4.8%) of draft foal castrations reported by Shoemaker et al.3 The differences between position and technique were statistically different with standing less likely to result in evisceration. Emasculation was less likely to result in evisceration than twisting. The safest technique in reference to evisceration was ligation, resulting in no eviscerations. However, in a survey of equine castration complications, Moll et al1 reported that the use of ligatures was thought to be associated with a higher rate of infection (13.5%) as compared to the non-use of ligatures (2.8%). Breed difference appeared to be significant with Quarter Horses and Thoroughbreds less likely and Standardbreds, Saddlebreds, and Others more likely to eviscerate. This survey was brief in order to encourage more practitioners to respond. A more detailed study is recommended to investigate differences when breed, method, and position are combined. As evisceration is only one of the possible complications of castration, it is not the only consideration in choosing which method is appropriate. Other factors such as the possibility of infection due to ligature placement, recovery

<table>
<thead>
<tr>
<th>Breed Comparison</th>
<th>Odds Ratio</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter Horse</td>
<td>0.3859</td>
<td>.007*</td>
</tr>
<tr>
<td>Paint Horse</td>
<td>0.8715</td>
<td>.789</td>
</tr>
<tr>
<td>Thoroughbred</td>
<td>0.1122</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Arabian</td>
<td>0.9975</td>
<td>.997</td>
</tr>
<tr>
<td>Appaloosa</td>
<td>2.4675</td>
<td>.079</td>
</tr>
<tr>
<td>Standardbred</td>
<td>3.1539</td>
<td>&lt;.001*</td>
</tr>
<tr>
<td>Morgan Draft</td>
<td>0.0090</td>
<td>.982</td>
</tr>
<tr>
<td>Tennessee Walker</td>
<td>1.5897</td>
<td>.518</td>
</tr>
<tr>
<td>Saddlebred</td>
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<td>.042*</td>
</tr>
<tr>
<td>Draft</td>
<td>1.7808</td>
<td>.0328</td>
</tr>
<tr>
<td>Other</td>
<td>2.9009</td>
<td>&lt;.001*</td>
</tr>
</tbody>
</table>

*Statistically significant at the 0.05 confidence level.

Quarter Horses and Thoroughbreds were less likely to eviscerate when compared with all breeds. Standardbreds, Saddlebreds, and other breeds were more likely to eviscerate when compared with all breeds.

<table>
<thead>
<tr>
<th>Method</th>
<th>Castrations</th>
<th>Eviscerations</th>
<th>Odds Ratio (95% CI)</th>
<th>P Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emasculator</td>
<td>42.146</td>
<td>51</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Twisting</td>
<td>4.440</td>
<td>11</td>
<td>2.09 (1.09–4.04)</td>
<td>.0272*</td>
</tr>
<tr>
<td>Ligature only</td>
<td>230</td>
<td>0</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

*Statistically significant at the 0.05 confidence level.

The odds ratio of evisceration when using the twisting technique was 2.09 times higher when compared with emasculation and there were no eviscerations if only a ligature was used.
from anesthesia, and operator safety in standing castrations should also be taken into account. It was not determined by this study whether eviscerations occurred when the practitioner was less experienced with the techniques or later in their career.

Acknowledgments
Thanks to American Association of Equine Practitioners and Equine Clinician’s Network members who participated in the survey.

Declaration of Ethics
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Conflict of Interest
The Authors have no conflicts of interest.

References

Appendix
Questions from castration survey:
1. How many equine castrations have you done in the last 10 years?
2. Of the equine castrations that you have done in the last 10 years, how many had bowel (jejunum or ileum) come through the inguinal canal? In other words, how many eviscerated (inguinal eventration)?
3. Please indicate the percentage of each of the breeds you castrated.
4. How many of each breed eviscerated/eventrated? Please indicate the method used (emasculating, emasculating and ligature, Henderson, Henderson and ligature, ligature only) on those that eviscerated and if they were standing or recumbent.
5. What percent of each method did you use for castration?
6. What percent do you do standing or recumbent?
7. Of the horses that eviscerated, what method and position did you use? Please list method for each horse (emasculate, emasculate and ligate, Henderson, Henderson and ligate, ligate only) and position (standing or recumbent). If more than one of the same breed, enter the number of individuals and method.
1. Introduction
Eyelid squamous cell carcinoma (SCC) is the most common location of periocular or ocular neoplasia. Horses with light pigmentation are more likely to develop periocular SCC. Recurrence rates of eyelid SCC reported in the literature are variable (25–67%).

2. Materials and Methods
Medical records of horses that underwent treatment for SCC of the eyelid confirmed by histopathology from April 2002–January 2018 were reviewed (n=36). Horses were included if follow-up examination of at least 3 months was available. Data were analyzed using a nonparametric Spearman correlation analysis to determine the association between tumor recurrence and age, sex, eye affected, eyelid involved, lesion size, use of surgical excision, surgical margins, and use of chemotherapy. Multivariable logistic regression was then used to determine the overall significance despite confounding variables.

3. Results
All horses affected by eyelid SCC were lightly pigmented, with the most common breed represented being the Paint (71%). Overall recurrence of eyelid SCC was 42% and occurred on average 2.6 years after treatment (median, 1.3 years). The multivariable logistic regression showed a decrease in recurrence when using a mask with greater than 90% UV light protection (p=0.028).

4. Discussion
SCC is a UV light-induced neoplasia and an important part of preventing recurrence is protecting the horse from additional UV light exposure.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.
Epinephrine Potentiates and Prolongs Lidocaine’s Ability to Attenuate Pain When Administered for a Palmar Digital Nerve Block in Horses

Ana Velloso Alvarez, LV*; John Schumacher, DVM, MS, DACVIM; and Fred J. DeGraves, DVM, PhD

Epinephrine combined with lidocaine as a 1:200,000 solution seems to be a safe drug that prolongs and intensifies the analgesic effect of 1% lidocaine solution in a palmar digital nerve (PDN) block in horses. Because the combination of lidocaine and epinephrine increased the duration and potency of a PDN block, it may have beneficial applications for lameness examinations and standing surgery. Authors’ addresses: Department of Clinical Sciences, College of Veterinary Medicine, Auburn University, Auburn, AL 36849 (Velloso Alvarez, Schumacher); Department of Agriculture, Ogden College of Science and Engineering, Western Kentucky University, Bowling Green, KY 42101 (DeGraves); e-mail: azv0023@tigermail.auburn.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
In human medicine, epinephrine added to a local anesthetic solution has been shown to intensify as well as prolong the analgesic effect of some local anesthetics. This study evaluates the ability of epinephrine to potentiate and prolong lidocaine’s ability to ameliorate lameness caused by foot pain when administered for a palmar digital nerve (PDN) block.

2. Materials and Methods
A crossover experimental design study was conducted. On separate occasions, a PDN block using 2% lidocaine, 1% lidocaine, or 1% lidocaine with epinephrine were performed. Gait at a trot was analyzed (Lameness Locator) every 5 minutes for the first 30 minutes and then every 15 minutes for a total of 2 hours after applying a PDN block to the lame limb. Heart rate and reaction to skin stimulation between heel bulbs were evaluated at each time point.

3. Results and Discussion
Horses treated with 1% lidocaine to which epinephrine had been added experienced longer amelioration of lameness, and their reaction to skin stimulation more closely correlated with amelioration of lameness than horses blocked using 1% lidocaine or 2% lidocaine. There were no changes in the heart rate, and skin reactions were not observed at any injection site.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors have no conflicts of interest.
Sodium Bicarbonate Speeds and Potentiates Analgesia of Median and Ulnar Diagnostic Neural Anesthesia Performed with Mepivacaine

Lindsey Boone, DVM, PhD, DACVS-LA*; John Schumacher, DVM, MS, DACVIM; Fred J. DeGraves, DVM, PhD; and Robert Cole, DVM, DACVR

When proximal neural anesthesia is performed, raising the pH of mepivacaine hydrochloride (MepHCl) by adding sodium bicarbonate (NaHCO₃) will speed the onset of analgesia and potentiate the nerve block. Authors’ addresses: Auburn University College of Veterinary Medicine, 1500 Wire Rd., Auburn, AL (Boone, Schumacher, Cole); Western Kentucky University, 1906 College Heights Blvd., Bowling Green, KY 42101 (DeGraves); e-mail: lhb0021@auburn.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Proximal diagnostic neural anesthesia requires more time to ameliorate lameness than diagnostic neural anesthesia of the distal limb. The objectives of the study were to determine if increasing the pH of mepivacaine hydrochloride (MepHCl) would significantly decrease the time to onset of analgesia when performing median and ulnar diagnostic neural anesthesia in naturally lame horses.

2. Materials and Methods
Median and ulnar diagnostic neural anesthesia was performed on the naturally lame limb of nine horses during two separate study periods, with a minimum washout period of seven days between peripheral diagnostic neural anesthesia. Diagnostic neural anesthesia was performed with either MepHCl alone or MepHCl mixed with NaHCO₃ (9 parts 2% MepHCl to 1 part 8.4% NaHCO₃). Lameness was evaluated objectively by using a wireless, inertial, sensor-based, motion analysis system (Lameness Locator) prior to the proximal diagnostic neural anesthesia and every 5 minutes following administration of the nerve block for at least 60 minutes.

3. Results
Resolution of lameness occurred significantly sooner for horses administered median and ulnar diagnostic neural anesthesia performed with MepHCl and NaHCO₃ than when diagnostic neural anesthesia was performed using only MepHCl.

4. Discussion
MepHCl buffered with NaHCO₃ significantly shortened the onset of analgesia in median and ulnar diagnostic neural anesthesia compared with MepHCl alone.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.
Conflict of Interest
The Authors have no conflicts of interest.
Tissue Heating and Cooling Properties of a Dry-Interface Pneumatic Sleeve Applied to the Equine Distal Limb

Kevin K. Haussler, DVM, DC, PhD, DACVSMR*; Shana R. Wolfer, BS; and C. Wayne McIlwraith, BVSC, PhD, FRCVS, DSc, DACVS

Therapeutic hot-cold temperatures can be delivered to the equine distal limb. Authors’ address: Gail Homes Equine Orthopaedic Research Center, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, 300 West Drake Rd., Fort Collins, CO 80523; e-mail: Kevin.Haussler@ColoState.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Rehabilitation of tendon injuries in horses often involves the application of cold water or ice therapies; however, heating is occasionally used to help increase collagen extensibility in fibrotic tissues. The objectives of this study were to 1) evaluate the time-temperature profiles during serial heating and cooling cycles using a contrast therapy device, and 2) assess whether the equipment could achieve therapeutic tissue temperatures (<15°C and >40°C) surrounding the flexor tendons.

2. Materials and Methods
Four adult horses with no previously diagnosed tendinopathies were used in the study. Fine-wire temperature probes were placed on the skin and implanted in three locations within the metacarpal region in both forelimbs: subcutaneously and deep to the superficial (SDFT) and deep digital flexor tendons (DDFT). Data was captured every 15 seconds during seven temperature cycles.

3. Results
Minimum and maximum tissue temperatures (°C) included: skin (12.6 ± 0.8; 42.4 ± 0.4), subcutaneous tissues (14.1 ± 0.8; 42.3 ± 0.3), deep to the SDFT (15.6 ± 0.9; 41.7 ± 0.3), and deep to DDFT (25.2 ± 1.2, 38.0 ± 0.7). The superficial tissues were heated and cooled to therapeutic ranges, but not the tissues deep to the DDFT.

4. Discussion
These results help define the physiologic responses of combined tissue heating and cooling within the equine distal limb.

Acknowledgments
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**Declaration of Ethics**
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**
The Authors have no conflicts of interest.
Osteochondral Fragments of the Pastern Joint: Performance Assessment after Arthroscopic Removal

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Osteochondral fragments in the dorsal proximal interphalangeal joint occur within the origin of the collateral ligament of the distal sesamoid bone and can be removed arthroscopically in young horses with a favorable prognosis for athletic performance. Authors’ addresses: 32100 N. Cave Creek Rd., Cave Creek, AZ 85331 (Moyer); Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070 (Bramlage, Ruggles, Embertson, Hopper); e-mail: christine.dvm@gmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Few reports describe arthroscopy of the proximal interphalangeal joint and quality of performance postoperatively. The purpose of this study is to describe the effect of osteochondral fragmentation in the dorsal equine proximal interphalangeal joint when treated by arthroscopic removal.

2. Materials and Methods
A review of medical records at a single hospital from 2000 to 2015 identified 56 horses (39 Thoroughbred flat racehorses and 17 horses of other breeds, aged 4 months to 4 years) that had arthroscopic surgery of the dorsal proximal interphalangeal joint for removal of osteochondral fragments. The athletic performance of the 39 Thoroughbred flat racehorses was compared to their 169 age- and sex-matched maternal siblings for the horse’s 2-year-old year, 3-year-old year, and career.

3. Results
Hind limbs (90%) were more commonly affected than fore limbs (10%). Fragments were located within the origin of the collateral ligament of the distal sesamoid bone. The likelihood of starting a race and race earnings of cases and maternal siblings were not significantly different during their 2-year-old year, 3-year-old year, or career.

4. Discussion
When fragments are removed arthroscopically from young horses, athletic performance is similar to matched controls.

Acknowledgments
Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
Histological Evaluation and Clinical Trial of Intra-Articular Polyacrylamide Hydrogel in Horses

Scott R. McClure, DVM*; Mike Yaeger, DVM, PhD, DACVP; and Chong Wang, PhD

A novel polyacrylamide hydrogel for intra-articular use has been evaluated in normal fetlock joints and in joints of horses with osteoarthritis. There have been no serious adverse effects and horses with osteoarthritis have improved following administration. Author’s addresses: 1354 270th Ave., Boone, IA 50036 (McClure); Department of Veterinary Pathology (Yaeger); Department of Veterinary Diagnostic and Production Animal Medicine (Wang), College of Veterinary Medicine, Iowa State University, Ames, IA 50011. e-mail: srmeqdr@gmail.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Polyacrylamide hydrogel is an inert viscoelastic supplement. In humans, polyacrylamide hydrogel has been found to be a safe and effective method of decreasing the clinical signs of osteoarthritis of the knee. Reports to date in the horse include a group of 43 horses with osteoarthritis of the carpus and fetlock and another group of 12 horses with pastern osteoarthritis; both studies yielded positive outcomes. Two studies of 4% polyacrylamide have been completed in the United States.

2. Study 1: Evaluation of 4% Polyacrylamide in Normal Fetlock Joints
Objective
The objectives of this study were to evaluate the clinical, histologic, and metabolic effects of polyacrylamide gel in normal fetlock joints. A blinded controlled in vivo evaluation of polyacrylamide hydrogel administered 7, 28, and 56 days prior to sample collection in 6 healthy horses was completed.

Materials and Methods
Each horse had each of the four fetlocks assigned to either a 7, 28, or 56 day or control group. Synovial fluid was collected prior to the administration of polyacrylamide hydrogel and again at the completion of the study for cellular and biomarker evaluation. At the completion of the study, gross examination and cartilage and synovial membrane histology were completed.

Results
There was a small but significant increase in cell count within the synovial fluid 7 days after administration of polyacrylamide. There were significant changes in the total synovial membrane histology score at all time points after administration of polyacrylamide. This was predominantly the result of numerous hypertrophic synoviocytes. Biomarkers indicated a small anabolic and catabolic effect 7 days after administration. The polyacrylamide was clearly visible on the surface of the synovium at 7 days, and more material appeared in the intersti-
tial spaces of the synovial membrane at days 28 and 56.

Conclusion
There were no detrimental effects seen with the administration of polyacrylamide in normal joints, and subsequent investigations in osteoarthritic joints are warranted.

3. Study 2: Field Trial Evaluation of Polyacrylamide in Horses with Naturally Occurring Osteoarthritis

Objective
The objective of this study was to investigate the effect of intra-articular polyacrylamide hydrogel in a field trial of horses with naturally occurring osteoarthritis.

Materials and Methods
Based on a lameness examination, including intra-articular localization and radiographic examination, horses were selected for inclusion in the study. Twenty-eight horses that met the study criteria were included in the primary outcome evaluation. Success was defined as at least a 1 grade decrease in lameness or a combined reduction of at least 3 among the scores for pain, range of motion, and joint swelling from treatment to day 45.

Results
There was a significant decrease mean (SE) lameness score from 2.34 (0.14) to 0.87 (0.21) with 23/28 (82%) of the horses improved based on the study criteria. Additionally, 21/28 (75%) of the horses met study criteria for improvement at day 90. Throughout the study period, there were 43 injections of polyacrylamide hydrogel, which included 8 horses that had the material administered two times, and there were no adverse events recorded in any horses.

Conclusion
The intra-articular polyacrylamide provided a prolonged decrease in lameness in horses with naturally occurring osteoarthritis.

Acknowledgments

Source of Funding
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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
How to Apply the Appropriate Farriery Principles to the Horse with Low Heels in the Hind Feet

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1. Introduction
Farriery for the hind limbs of the horse has not been studied to the extent of fore limbs farriery, and there is minimal information published in the clinical or research literature. The low heel “bull nose” conformation of the hind foot has become so prevalent in performance horses that it is often considered normal (Fig. 1). The correlation between low or underrun heels and soundness has been well documented in the forefeet, giving little reason to believe the same syndrome does not occur in the hind feet when the structural integrity of the hoof capsule is compromised.1–3 Horses with structural damage to the plantar section of the hoof capsule will suffer the same consequences associated with the hoof capsule as the forefeet; however, the hind feet are not generally affected with diseases that affect the internal structures of the foot as noted in the forefeet. This difference may be due to the anatomy of the hind limbs and the propulsionary function of the hind feet vs. the weight-bearing function in the forefeet. Not only can this low heel “bull nose conformation of the hind feet be a source of hind limb lameness, but this abnormal hind foot conformation can also have an adverse effect on the musculoskeletal system of the hind limb.2,4–8 The low heels in the hind feet often lead to a subtle bilateral lameness or poor performance, which is often attributed to the proximal suspensory ligament, hock, stifte, or back pain.6,8 However, horses presenting with subtle bilateral hind limb lameness or poor performance with this abnormal foot conformation are not approached in the same manner as the horse with similar forefeet conformation, where reliance is placed on evaluating hoof conformation, hoof testers, perineural anesthesia, and radiographs to localize the region of discomfort. Due to the temperament of many horses, diagnostic nerve blocks and radiographs of the hind foot/digit are often challenging for the clinician to perform and are, therefore, often avoided. Treatment in these cases is often based on assumptions, manipulations/flexions of the hind limb, and previous experience of the clinician or trainer rather than a definitive diagnosis. With or without a definitive diagnosis, appropriate farriery to correct this low heel hind foot conformation should always be part of the treatment, especially when a lameness such as
proximal suspensory ligament desmitis or distal tar-
sitis has been diagnosed.

Accepted farriery for low heels in the hind feet has
been to provide heel elevation regardless of the foot con-
formation or integrity of the hoof capsule. Long egg
bar shoes with wedge pads are generally used
for this purpose. This is also the farriery that is
generally prescribed for lameness localized to the
hock or stifle, yet there is no documentation that
confirms that heel elevation exerts any significant
influence on any section of the hind limb above the
distal interphalangeal (DIP) joint.9 Furthermore,
heel elevation will tend to exaggerate a heel first
landing and thus increase the pressure exerted on
the hind feet that have existing low or underrun
heels, which appears to compromise the structures
of the hoof capsule further and lead to additional
lameness problems.

2. Hind Limb Movement

Before discussing farriery for the hind foot, a brief
description of hind limb movement is essential to
understand the propulsionary function of the hind
limbs.10 Protraction, the foot lifting from the ground,
begins with the flexion of the hip, stifle, and hock;
this action overcomes the inertia of the hind limb so
minimal muscular work is done. The hip joint is
flexed by the iliopsoas muscle, the stifle is flexed by
the biceps femoris muscle, and the hock flexes as a
result of the reciprocal apparatus. The fetlock also
automatically flexes because of the tendinous nature
of the superficial digital flexor tendon that travels
from the hock to the pastern.

Retraction is accomplished by the middle gluteal
muscle, which is attached to the femur above the
center of rotation (the hip joint).10 As the middle
gluteal muscle contracts, it rotates the whole limb
backward. The hamstring muscle group (semiten-
dinosus, semimembranosus, and bicep femoris) runs
behind the center of rotation, so they form the sec-
ond part of retraction. This movement is accompa-
nied by contraction of the quadriceps muscles, which
extends the stifle and, consequently, the hock and
fetlock.

The stance phase of the stride starts with foot
impact. Initially, the vertical impact stops but
horizontal movement continues, which means the
hoof slides forward before full weight bearing
takes place. At full weight bearing, the retractor
muscles continue to be engaged and drive the
horse’s body forward with the foot fixed to the
ground. An important part of the forward pro-
 propulsion provided by the hind limb is the opening or
extension of the hock joints during the second half
of the stance phase.

At landing, the forefeet have the greatest vertical
force and also experience peak DIP joint flexion,
while the hind feet have a greater vertical force
during the stance phase, with peak DIP joint flexion
following horizontal movement; this would imply
the forelimb is a pendulum that is swinging and
absorbing force, while the hind limb is grabbing and
generating force.10

3. A Good Hind Foot

The authors are reluctant to use the term “normal”
to describe hind foot conformation. The terms
good, ideal, or functional may be more appropriate,
as foot conformation with its inherent shape is as-
associated with many variables such as genetics,
breed, limb conformation, and farriery. The hind
foot has a steep hoof angle, the shape is narrow or
conical, the toe is pointed, and the sole has a much
deeper concavity when compared with those of the
front foot. In the well-conformed hind foot, the lat-
eral wall will have some degree of flare while the
medial wall will be straight, the amount of which
will be conformationally dependent. The shape of
the hind feet is an indication of being designed for
primary propulsion/traction and secondary weight
bearing. The front foot is generally as wide as it is
long, whereas the hind foot is longer than it is wide.
Looking from the side, a good hind foot will have a
straight hoof pastern axis, even growth rings distal
to the coronet from the toe to the heel, and approxi-
mate proportions on either side of the widest part of
the foot (Fig. 2A). Looking at the solar surface of
the foot, a line drawn across the widest part of the
foot should divide the foot into approximate propor-
tions on either side of the line. Considering the
shape of the foot, it appears that the widest part of
the foot is located further plantar in the hind foot
when compared with that of the front foot (Fig. 2B).
As the widest part of the foot is generally located
5–10-mm dorsal to center of rotation (COR), this
difference between the fore and hind feet could be
verified using lateral radiographs.a The first au-
dor did a small extemopore study on a limited num-
ber of hind foot lateral radiographs supplied by two
large equine referral centersb,c that were considered
to be representative of acceptable conformation for a
hind foot. The radiographs were measured and the
proportions on either side of the COR were com-
pared with forefoot lateral radiographs. The propor-
tions generally found on a front foot with good

Fig. 1. A moderate to severe low heel “bull nose” conformation of
a hind foot.
conformation are 53–57% dorsal to the COR and 43–47% palmar to the COR.\textsuperscript{c,11} In all radiographs, the COR was found to be further plantar in the hind foot, which significantly decreased the ground surface of the foot plantar to the COR. Furthermore, in all radiographs, the digital alignment was not completely straight, as the middle phalanx was mildly displaced in a distal plantar direction relative to the distal phalanx (Fig. 3).

4. Clinical Examination

Observations
Performance problems or soundness issues that have been associated with this hind foot conformation are a subtle bilateral lameness, poor performance, a stiff hind limb gait, lack of impulsion, change in attitude, or bad behavior. If the "bull nosed"/underrun heels hind foot conformation is moderate to severe, the horse may assume a stance where the foot is placed further forward than normal in relation to the vertical axis of the limb and the main mass of the hindquarters, thus giving the horse a “sickle hocked” appearance. In one recent report, it was stated that this type of stance could be consistently related to gluteal pain.\textsuperscript{4} Another helpful method to evaluate stance is to view a trajectory by using a line starting at the ground through the angle formed by the coronet of the hind foot. With low heels, this trajectory line will project to the elbow of the forelimb rather than to the palmar surface of the radius just above the carpus with good hind foot conformation (Fig. 4).\textsuperscript{12} In motion, the horse may show a short, stilted gait with a markedly shortened cranial phase of the stride; there may be frequent stumbling noted and the signs of discomfort may increase when the horse is trotted in a circle. On hoof tester examination, the horse may show discomfort at the inner part of the sole just dorsal to the apex of the frog and at the angle of the sole at the heels. The sole/heels may also deform in these areas when pressure is applied depending on the amount of structural damage. If the abnormal hoof conformation is suspected as a source of any of the above problems, the authors suggest, if possible, to do a posterior digital nerve block and then with the rider/trainer mounted, rule out a hind foot lameness. An experienced rider will immediately be able to tell if there is a difference in the movement of the horse and its attitude. It should be noted that many horses with low heels in the hind feet do not

Fig. 2. A, Lateral view of a hind foot with good conformation. Black line is the hoof pastern axis, red line is the middle of the foot, yellow line is the proportions of foot on either side of the middle of the foot, and green line is the appropriate length of a hind shoe. B, Solar view of a hind foot. Red lines are the widest part of foot and the proportions of ground surface on either side, and the yellow line is the base of the frog. Note the widest part of the foot is located further plantarly compared to the forefoot.

Fig. 3. A, Acceptable conformation for a forefoot (Courtesy Dr. Andrew Parks). B, Acceptable conformation for a hind foot (Courtesy Dr. Kurt Selberg). Yellow line is COR, green line is widest part of the foot, brown line is distance from COR to dorsal hoof wall, and red line is ground surface on the solar surface of the foot.
block sound with posterior digital nerve blocks because this hind foot conformation may lead to pain in the hocks, proximal suspensory ligament and gluteal and lumbar region.4–6,8

The Low Heel “Bull Nose” Foot Conformation

This abnormal conformation of the hind feet is easy to recognize. When looking at the limb from the side, the digit will show a broken back hoof pastern axis. The slope of the coronary band from the toe to the heel will have an acute angle of 40–45°, and the coronet will bend distally at the heel to become almost vertical. The bulbs of the heels will be prolapsed plantar to the heels of the hoof capsule and will form a “knob”-shaped appearance that can be seen lying against the shoe. The hair on the coronet at the heels may project horizontally rather than lying flat against the hoof due to excessive load on the associated hoof wall. There will be a disparity in the growth rings below the coronet from the toe to the heel, with the growth rings wide apart at the toe and then tightly packed at the heel. The dorsal hoof wall will assume a “bull nose” appearance (Fig. 5A). Looking at the foot from behind, the frog will be large and bulbous from the constant stimulation with the ground, a ledge will form in the frog from bearing weight, and it will be situated well below the hoof wall with the bulk of the frog now located between the two branches of the shoe (Fig. 5B). The solar surface of the foot will show an inclined plane of the entire frog from the base to the apex in a dorsal cranial direction toward the coronet. This inclined plane or angle will match the angle of the solar border of the distal phalanx in the hoof capsule. The toe area on the solar surface of the foot will show a deep or exaggerated concavity between the apex of the frog and the inner branch of the shoe instead of a steep, yet smooth transition of the sole from the frog to the sole wall junction. There will usually be a palpable “trough” located just dorsal to the apex of the frog (Fig. 5C). Upon removing the shoe, the end of the heel of the hoof capsule is located well forward from the base of the frog and the horn tubules will be parallel with the ground. The hoof wall at the heel will be thin, the bars may be damaged or missing, and the angle of the sole will be absent. Lightly paring the area adjacent to the hoof wall at the end of the heel with a hoof knife will often show moderate to severe hemorrhage from the pressure of the damaged hoof capsule against the shoe. When the foot is placed on the ground, total weight bearing will be placed on the frog, which is located distal to the ground surface of the hoof capsule, and many horses will be reluctant to stand on it when the opposing limb is lifted off the ground. As noted previously, hoof testers placed on either side of the heel at the angle of the sole will often elicit a painful response and the structures will deform (Figs. 6A, 6B).

Radiographs

A lateral radiograph of the hind foot will show a broken back hoof pastern axis, with the middle phalanx (P2) being displaced plantar and distal relative...
to the distal phalanx (P3) during weight bearing. This places excessive stresses on the plantar section of the hoof capsule. The COR is located further plantarly with this abnormal foot conformation, thus decreasing the ground surface in the plantar section of the foot. The soft tissue structures (frog, digital cushion) in the plantar section of the foot have prolapsed plantarly to the shoe, forming a "knob"-shaped appearance. The angle of the solar border of the distal phalanx at the heels is lower than the dorsal margin of the distal phalanx (i.e., a negative plantar angle). The sole depth below the dorsal margin of the distal phalanx is markedly increased relative to the sole depth at the heel, and the perimeter of the dorsal margin of the distal phalanx can be seen migrating toward the dorsal hoof wall. The displacement of the distal phalanx results in the “bull nose” appearance of the dorsal hoof wall (Fig. 7).

**Farriery**

The amount of improvement that can be achieved with the appropriate farriery will obviously be proportional to the severity or the amount of distortion present. Damage to the plantar section of the hind feet is easier to improve than in the forefeet, possibly due to the anatomy and the difference of the load encountered on the hind limbs. The initial goal of the farriery is to make the plantar section of the foot “load sharing” such that the hoof wall and the frog are on the same plane. The first step of the farriery process will be to address the frog being located below the hoof wall. This will depend on the severity; if mild, the horse could have its shoes removed the day before being shod and housed on a firm surface, or if more severe, allowed to go without hind shoes for 3–5 days, which can be very effective. To begin the trim, the shoes are removed and the toe length is reduced from quarter to quarter according to the sole depth. Caution is advised when decreasing the toe length in this type of foot conformation, as the amount of sole depth noted on the radiograph or determined from the incline of the frog can be misleading. The dorsal margin of the bone migrates dorsally and therefore stretches the width of the dermis, a change which may not be recognized on the radiograph (Fig. 8A). Therefore, aggressive trimming at the toe will often result in seepage of blood at the sole wall junction as the dermal tissue is being encroached. It may be prudent to reduce the amount of sole depth gradually over two shoeing intervals. After the hoof wall is removed on the solar surface of the foot, additional horn is removed from the outer hoof wall to create even or uniform hoof wall thickness from quarter to quarter. The horse is then placed on a firm surface, which places pressure on the frog that quickly assumes the same plane as the heels on either side.

**Fig. 6.** A, Hind foot from Figure 5 with shoe removed. Note the frog located below ground surface of the foot and the horse standing on the frog rather than the hoof capsule. B, A necropsy specimen from a horse with severe low heels in the hind foot. Note the hemorrhage in the sole. (Courtesy Michael Savoldi).

**Fig. 7.** Radiograph of a foot with low heels “bull nose” conformation of the hind foot. Note the COR (red line) located further plantarly than the forefoot and the decreased ground surface (yellow line) plantar to the COR. Also note the negative angle of the solar border of the distal phalanx.
If the frog prolapse is severe, the approach can be modified and the time frame shortened. The hind shoes are removed a day or two before the horse is due to be shod, and the foot is trimmed as described above. A frog plate is cut from a degree pad to match the frog, and the front of the pad is left intact to form a half moon design. The pad is attached to the foot with two small nails at the toe, and the foot is wrapped in a medicated poultice that has been soaked in hot water and then secured to the foot with brown gauze and elastic tape (Fig. 8B). The horse is placed in a stall on a firm surface for 24–48 hours. When the wedge pad is removed, the frog will be compressed between the heels, forming a flat even plane which includes the frog and both heels. The horse will then be ready to have shoes applied, paying strict attention to the trimmed foot.

A line is now drawn across the widest part of the foot. Any additional horn at the heels can be removed using the rasp in a horizontal direction across the heels and frog so the hoof wall approaches the base of the frog to create as much ground surface as possible. Care must be taken to keep the frog and both heels in the same plane. When the hoof wall and the frog are on the same plane, the load is shared across the plantar section of the foot. The foot is now ready to have a sturdy steel shoe fitted and applied. The first author fit shoes to the hind feet in a similar manner to the front feet by using the line drawn across the widest part of the foot placed in the middle of the shoe. However, in the hind feet, the widest part of the foot will be located further plantar than the forefeet; therefore, additional shoe length is required to create the desired proportions on either side of the COR (Figs. 9–11). Looking at the shod hind foot from the side, the branch of the shoe should extend to or close to the point that coincides with a vertical line dropped from the hairline at the bulb of the heel. If the branch of the shoe extends beyond the vertical line or if the foot is not trimmed appropriately, the length of the shoe will create excessive leverage on the heels. In order to keep the frog and hoof wall on the same plane for the first shoeing interval or if mild heel elevation is necessary, a metal or aluminum heel plate or a 2° leather wedge can be placed under the shoe at the heels as long as the shoe is fitted in the manner described above. This will con-
centrate the load across the frog and heels rather than behind the heels, which is the case with a long shoe or trailers. The plate or wedge will also prevent the frog from descending toward the ground between the branches of the shoe. This is usually a temporary measure and it can be discontinued once the heels have stabilized.

5. Summary
The low heel “bull nose” foot conformation of the hind feet is often overlooked as a cause of poor performance or lameness in the hind limbs. This abnormal foot conformation may play a dual role in hind limb soundness. Firstly, the overload and damage to the plantar section of the foot can cause pain and a subtle bilateral lameness. Secondly, pain and/or the altered biomechanics of the foot will cause changes in hind limb movement. The changes appear to affect flexion of various joints, strain on ligaments, hoof and limb flight, hoof landing/loading, and muscle tension. Veterinarians and farriers frequently use specialty shoes or modify existing shoes in an attempt to relieve pain and therefore improve overall hind limb mechanics. However, it is unclear whether these modifications have an effect on hind limb biomechanics, as there is no research or current literature to support these modifications. It is the authors’ opinion that farriery begins with the appropriate trim, with the correct size/placement of the shoe with any subsequent modifications being secondary. The appropriate trim improves many hind limb issues by providing increased ground surface in the plantar section of the foot combined with a shoe of sufficient length so that the transition from loading to propulsion minimizes dorsiflexion of the fetlock and hock. In turn, this allows the toe to push off, elevating the limb into the swing phase, resulting in a smoother transition of force from the hind limb through the sacroiliac and lumber regions.

The incidence of this low heel “bull nose” hind foot conformation in performance horses has reached epidemic proportions in recent years. There are a myriad of theories/thoughts regarding how to trim the palmar/plantar section of the foot; however, the authors feel that inappropriate trimming of the heels decreases the ground surface in the plantar section of the foot and the application of shoes that are too small may be the inciting cause of this foot confrontation.

Fig. 10. Lateral radiograph of a low heel “bull nose” conformation of the hind foot before and after farriery. Note the difference in the foot conformation after the appropriate trim and a size larger shoe. Again, note the increased ground surface plantar to the COR. (Courtesy Dr. Hans Castelijns).

Fig. 11. The goal of hind foot farriery is to create a foot that has approximate proportions or ground surface on either side of the widest part of the foot. Note the branches of the shoe used to increase ground surface in the plantar section of the foot.
Treatment to address this foot conformation is a joint venture between the veterinarian and the farrier. It is essential for both professions to be aware of this problem and its effects not only on the foot but the hind limb above. Perineural analgesia, when possible, will show the prevalence of foot pain in the hind feet and the increased use of radiographs, when possible, will help guide the appropriate farriery. A working knowledge of foot biomechanics and good basic farriery principles make the treatment for this condition straightforward.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.

References and Footnotes

aParks AH. (personal communication) 2018.
bTexas Equine Hospital, Bryan, TX 77807.
cVirginia Equine Imaging, The Plains, VA 20198.
dAnimalintex®, 3M Animal Care Products, St. Paul, MN 55144.
Correlational Characteristics of Hoof Biomechanics and Anatomy in Athletic Horses at Midstance

Babak Faramarzi, DVM, CVA, MSc, PhD*; An Nguyen, BS; and Fanglong Dong, PhD

Hoof anatomy is correlated with the hoof biomechanics thus abnormal anatomy may alter force distribution patterns and predispose the horses to injuries; such injuries are not limited to the foot and may affect proximal structures. Authors’ addresses: College of Veterinary Medicine (Faramarzi); Graduate College of Biomedical Sciences (Dong), Western University of Health Sciences, Pomona, CA 91766; University of California–Los Angeles, College of Engineering, Los Angeles, CA, 90095 (Nguyen); e-mail: bfaramarzi@westernu.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Repeated loading during activities such as regular exercise causes changes in the magnitude of the applied stress on the hoof. Variations in hoof anatomy may alter stress distribution, thus predisposing horses to pathologies and lameness; however, experimental studies are scarce. The objective was to investigate the correlation between hoof kinetics and anatomy in athlete horses.

2. Materials and Methods
Nine unshod athlete horses were walked over a pressure plate, and force (F), contact pressure (CP), and contact area (CA) were recorded. Using digital radiography and digital pictures, 55 variables of internal and external anatomy of the hoof were measured. Correlations between biomechanical and anatomical measurements were investigated using Pearson’s rank correlation coefficient. P-values ≤ 0.05 and r values ≥ 0.5 were considered.

3. Results
Toe angle was negatively correlated with CA (r = −0.71). Several heel height measurements were negatively correlated with F on the toe (0.63 ≤ r ≤ −0.58), implying an obvious trend. Larger medial wall angle was correlated with higher F, CP, and CA on the medial aspect of the hoof (−0.68 ≤ r ≤ −0.58). Measurements of the dorsal hoof wall thickness and length/width of the distal phalanx (P3) showed correlations with F and CP (0.5 ≤ r ≤ 0.72) while the height of the P3 was negatively correlated with CA (r = 0.72).

4. Discussion
Patterns of correlations confirmed the relationship between hoof anatomy and hoof biomechanics, signifying the importance of hoof anatomy. These findings provide valuable information on the significance of changing the hoof anatomy, e.g., therapeutic trimming/shoeing in addressing hoof pathologies.

Research Abstract—for more information, contact the corresponding author

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
The Relationship between Sagittal Hoof Conformation and Hindlimb Lameness in the Horse

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Horses with hindlimb lameness localized to the distal tarsus and proximal metatarsus, but not the stifle, were more likely to have negative/neutral plantar angle of the distal phalanx (PADPs). Authors’ address: Colorado State University, 300 West Drake Rd., Fort Collins, CO 80523; e-mail: Lynn.Pezzanite@colostate.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
The identification of factors associated with lameness could be one method to decrease lameness incidence and prolong the competitive life of the equine athlete. The objectives were to determine whether there is an association between sagittal-plane hoof balance and hindlimb lameness.

2. Materials and Methods
Eighty client-owned horses with hindlimb lameness localized with regional anesthesia (cases) and 80 horses with no detectable hindlimb lameness (controls) were prospectively enrolled. Lameness cases were categorized by location (stifle, tarsus, proximal metatarsus, and other sites). Lateromedial radiographs were performed of hind hooves and plantar angle of the distal phalanx (PADP) determined. Mean PADPs were calculated. Logistic and linear regression were used to analyze PADPs. Odds ratios were calculated. Significance set at $P < .05$.

3. Results
Mean PADP was 1.76° less in cases than controls. Mean PADP was significantly less in horses with lameness localized to the tarsus and proximal suspensory, but not the stifle. Lame horses were 3.8 times more likely to have a negative/neutral PADP. Lameness localized to the tarsus and proximal suspensory were 5.2 and 5.5 times more likely to have a negative/neutral PADP.

4. Discussion
It is unknown whether the negative/neutral PADP contribute to lameness or lameness resulted in lower PADP. Corrective farriery to improve PADP may be investigated as one component in the prevention or treatment of hindlimb lameness localized to regions proximal to the foot.

Research Abstract—for more information, contact the corresponding author

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Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.
Intra-Articular Administration of Platelet-Rich Plasma in Horses Using a Synovitis Model

Cole B. Sandow, DVM, MS*; Carlos Aguilar, MVZ; and Laura Riggs, DVM, PhD, DACVS, DACVSMR

Leukocyte-poor platelet-rich plasma improved lameness scores, but did not improve the synovial environment in an experimental model of synovitis. Authors’ address: Louisiana State University School of Veterinary Medicine, Skip Bertman Dr., Baton Rouge, LA 70803; e-mail: csandow@lsu.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
The clinical intra-articular use of platelet-rich plasma (PRP) has been used with increased frequency in cases of osteoarthritis outpacing controlled research evaluating its effects and the ideal composition of PRP for intra-articular use is yet to be determined.

2. Materials and Methods
This IACUC-approved study used a crossover design. A transient, self-limiting synovitis was induced in the metacarpophalangeal joint of six horses. They randomly received intra-articular administration of a saline control or a leukocyte-poor PRP (LP-PRP), and following a 2-week washout period, the opposite treatment was performed in the contralateral limb. Serial lameness examinations and synovial fluid evaluations were performed evaluating prostaglandin (PG) E2, interleukin-1 receptor antagonist (IL-1Ra), and collagen type II cleavage (C2C). A two-way, repeated-measures ANOVA was used to determine statistical significance (P < .05).

3. Discussion
Clinical relevance of LP-PRP is improved lameness scores, but did not improve the synovial environment with a lipopolysaccharide (LPS) model of synovitis. Multiple injections, different synovitis model, or PRP composition may have varied results. Further evaluation is needed to determine the ideal composition and injection protocol for PRP.

Acknowledgments
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Conflict of Interest
The Authors have no conflicts of interest.
Application of a Ridden Horse Ethogram to Video Recordings of Lame Horses Before and After Diagnostic Analgesia

Sue Dyson, MA, Vet MB, PhD, Diplomate ECVSMR, FRCVS*; and Jan Van Dijk, DVM, PhD

Application of a ridden horse ethogram can be used to determine the likely presence of musculoskeletal pain in the majority of lame horses, by both trained and nontrained assessors. Authors’ addresses: Centre for Equine Studies (Dyson) and Centre for Preventative Medicine (Van Dijk), Animal Health Trust, Lanwades Park, Kentford, Newmarket, Suffolk, CB8 7UU, United Kingdom; e-mail: sue.dyson@aht.org.uk. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Identification of low-grade lameness is challenging. A whole-horse ridden ethogram (a catalogue of behaviors with descriptions) has been developed, describing 24 behavioral markers. Comparison of nonlame and lame horses indicated that the presence of at least eight behavioral markers was likely to reflect musculoskeletal pain.

2. Objectives
The objectives were to 1. apply the ridden horse ethogram by a trained assessor to horses before and after musculoskeletal pain had been substantially improved using diagnostic analgesia, and 2. assess the repeatability of the ethogram application among untrained assessors.

3. Methods
Video recordings of 21 horses were reviewed by a trained assessor and 10 untrained assessors.

4. Results
Trained assessor: The number of behaviors exhibited by lame horses before diagnostic analgesia ranged from 3 to 12 of 24 (median, 10; mean, 8.9). After lameness and overall performance had been substantially improved using diagnostic analgesia, the number of behaviors ranged from 0 to 6 of 24 (median, 3; mean, 3.0). The decrease in behavior scores after diagnostic analgesia was significant (Wilcoxon Signed-Rank, \( P < .0001 \)). Agreement between the untrained assessors and the trained assessor was moderate and poor before and after analgesia, respectively (Fleiss Kappa 0.49, 0).

5. Discussion
Each horse acted as its own control (repeated measures design); the only variable was removal of pain. Reduction in behavior scores after resolution of musculoskeletal pain indicates that these behavioral markers are a likely reflection of pain. These behaviors may be easier to recognize than low-grade lameness, facilitating identification of musculoskeletal pain.

Acknowledgments

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Conflict of Interest
The Authors have no conflicts of interest.
Acoustic Myography to Evaluate the Health and Function of the Equine Hindlimb Proximal Suspensory Ligament

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Acoustic myography is a useful diagnostic tool to determine the health of the hindlimb proximal suspensory ligament. Authors’ addresses: Virginia Equine Imaging, 2716 Landmark School Rd., Middleburg, VA 20198 (Allen, Chavers); Faculty of Health & Medical Sciences, University of Copenhagen, Copenhagen 1870, Denmark (Ahmed, Callesen, Harrison); e-mail: kallendvm@aol.com. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
An objective system for evaluation of the proximal suspensory ligament (PSL) is needed to hasten appropriate diagnosis and treatment of injury. Acoustic myography (AMG) provides a quantitative assessment of tissue function. The purpose of this study was to determine whether AMG is capable of differentiating healthy from injured hindlimb PSLs.

2. Materials and Methods
Complete lameness evaluations were performed on 96 horses. AMG signals were acquired on both hindlimbs. Diagnostic analgesia and appropriate imaging were performed to reach a causative diagnosis for each hindlimb lameness. Results were analyzed by blinded evaluators via CURO® algorithms and scored from 0 to 10 (poor to optimal). Data were tested for normal distribution and equal variance. Differences between means were tested for statistical significance using an ANOVA (one-way) with Tukey-Kramer multiple-comparison tests.

3. Results
Eighty-five horses provided adequate data. Fifteen (17.7%) horses were sound, 48 (56.5%) horses had a PSL injury, 4 (4.7%) horses were recovering from prior PSL injuries, and 18 (21.1%) horses had another cause of hindlimb lameness. There was a significant difference ($P < .001$) in CURO scores between horses with PSL injury and all other groups, with the majority of horses with PSL injury scoring less than 5.

4. Discussion
AMG was able to discriminate between healthy and injured PSLs, regardless of degree of lameness or concomitant pathologies.

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Conflict of Interest
A.P. Harrison is currently trying to commercialize the CURO System (CURO.diagnostics) and is establishing a company to cover the costs of future development. The CURO system was provided to Virginia Equine Imaging at no cost. Virginia Equine Imaging and its staff and doctors were not compensated for this study.

Footnote
*MyoDynamik ApS, Frederiksberg C, Denmark.
An Investigation of the Association between Hindlimb Conformation and Suspensory Desmopathy in Sports Horses

Jenny Routh, BSc, BVSc; Camilla Strang, MSc, BVetMed; Siobhan Gilligan, MSc; and Sue Dyson, MA, Vet MB, PhD, Diplomate ECVSMR, FRCVS*

There is an association between hindlimb proximal suspensory desmopathy and large tarsal angles. Authors' addresses: Centre for Equine Studies (Routh, Gilligan, Dyson) and Centre for Preventative Medicine (Strang), Animal Health Trust, Lanwades Park, Kentford, Newmarket, Suffolk, CB8 7UU, United Kingdom; Current address for Strang: Royal Veterinary College, Hawkshead Lane, Hatfield, Hertfordshire, AL9 7TA, United Kingdom. e-mail: sue.dyson@aht.org.uk. © 2018 AAEP.

1. Introduction
Proximal suspensory desmopathy (PSD) is a common cause of hindlimb lameness in sports horses. The objective of this study is to describe hindlimb conformation in horses with and without PSD. This is a prospective observational study.

2. Materials and Methods
Horses examined over 1 year with a definitive diagnosis for lameness were included (n = 193). Markers were placed on predefined landmarks. Lateral photographs were acquired from left and right sides with the horse standing squarely, using standardized techniques, with each metatarsus perpendicular to the ground, aligned to the tuber ischii marker. The tarsal and metatarsophalangeal angles were measured using Image Measurement. Orthopaedic diagnosis, breed, work-discipline, and age were recorded. Control horses did not have suspensory desmopathy.

3. Results
Repeatability of limb positioning and angle measurements was good. Horses with PSD had larger tarsal angles ("straighter hocks") than controls (P = .003). The proportions of Warmblood-type horses and dressage horses with PSD were different to those of other breeds and work-disciplines (P = .001, P = .02, respectively). A final logistic regression model demonstrated a significant effect of tarsal angle on outcome when work-discipline and breed were accounted for. There was an 11% increase in the odds of PSD for every degree increase in tarsal angle (CI, 1.004–1.220; P = .04). There was no association between PSD or suspensory branch injury and metatarsophalangeal joint angle.

4. Discussion
Standardization of positioning the horse is crucial for acquiring repeatable measurements. A larger study is required to assess the relationship between metatarsophalangeal joint angles and suspensory desmopathy.
Acknowledgments

Declaration of Ethics
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Conflict of Interest
The Authors have no conflicts of interest.
How to Obtain and Evaluate Oblique Projection Radiographs of the Equine Cervical Spine

Natasha Werpy, DVM, DACVR; and Leah Griffith, DVM

1. Introduction
Radiographs are frequently used for diagnosis of degenerative, developmental, and traumatic abnormalities of the cervical spine in equines. Caudal cervical arthrosis of the articular process joints is a common finding and has been documented as a cause of neck pain, stiffness, forelimb lameness, ataxia, and paresis. \(^1\) Clinical signs can be a result of static spinal cord compression due to osteophyte formation and/or hypertrophy of the periarticular soft tissues. In addition, new bone formation extending into the intervertebral foramen can result in spinal nerve root compression. \(^2\) Additional abnormalities that may be diagnosed on radiographs include fractures, osseous cyst-like lesions, osteochondral lesions, cervical vertebral stenosis, and intervertebral disc space remodeling or collapse.

The standard technique for radiographic evaluation of the cervical spine includes lateral projections in a standing horse. When properly positioned, a lateral radiograph of the cervical spine will result in the left and right articular process joints as well as the transverse processes being superimposed over each other. \(^1\) This positioning is useful for evaluation of specific regions, such as intervertebral disc spaces and the sagittal vertebral canal diameter. When evaluating lateral radiographs, arthrosis of the articular process joints is identified as overall enlargement in size due to the presence of periarticular new bone on the dorsal margin and/or ventral margins of the joint. \(^1\) However, because this projection is not perpendicular or parallel to the normal anatomic orientation of the articular process joints, interpretation of the periarticular margins and articular surfaces is difficult. In addition, due to the superimposition of the left and right articular process joints, it is nearly impossible to distinguish which joint a detected abnormality is affecting or whether the abnormality is biaxial. Superimposition of the articular processes may also result in decreased conspicuity or nonvisualization of lesions (Fig. 1).

The widely accepted practice for all other synovial joints in the horse is to acquire at least two orthogonal radiographs. The translation of a three-dimensional structure into a two-dimensional image invariably results in an inadequate representation of certain lesions on a single projection, depending on their location in relationship to the x-ray beam. For joints, this typically involves orienting the beam parallel with the joint space to maximize visualization of the articular surfaces and periarticular margins, where most clinically significant findings will be found. Dorsal-ventral oblique pro-
jections of the cervical spine help to eliminate these difficulties, as they result in separation of the left and right articular process joints, and the beam is either parallel or perpendicular to the joint space and margins.

The technique for obtaining oblique projections of the cervical spine in horses has been described and is increasingly being used to gain further information but is not routinely included in a complete study. In human radiography, a minimum of two orthogonal views (cranial-caudal and lateral) are standard for all patients with a clinical risk of cervical trauma. Oblique views are recommended for patients with a medium or high risk based on history and clinical evaluation, in all cases, or in those with no or questionable findings on initial evaluation of the standard projections. In one human study, oblique radiographs resulted in the diagnosis of abnormalities that were either not identified on a standard lateral view or were subtle on the lateral view (defined as missed on the initial review of the films but noted on retrospective review).

The reliable identification and interpretation of radiographic abnormalities is important in equine practice, both for diagnosis of abnormalities resulting in clinical signs and as a screening tool in purchase examination for abnormalities that may become clinical. Therefore, oblique radiographs should be incorporated into the standard radiographic examination of the cervical spine. Because the cervical vertebrae are surrounded by a large muscle mass, preventing visualization, and the articular process joints are at an oblique angle, they are more difficult to orient properly for radiographs than joints in the distal limb. Correct positioning is desired to gain the most information. A description of the methods used to obtain properly positioned oblique radiographs of the cervical spine and interpretation are discussed.

2. Materials and Methods

Horses are positioned in the same manner as a standard lateral projection, and sedation of clinician’s choice is often used to facilitate positioning. The horse should be standing square, with the front limbs placed just behind the vertical plane to reduce the amount of musculature in the caudal cervical region. The head and neck should be in a neutral position. A lateral-dorsal, lateral-ventral oblique is being taken in this picture. However, the appropriate beam angle can change based on the head and neck position.
position and held straight in the sagittal plane.\textsuperscript{2} It is important to note that neck position will alter the position of the vertebrae and the articular process joints, so the amount of dorsal to ventral angulation of the x-ray beam will vary slightly depending on the head and neck position. In the authors’ opinion, holding the cassette along the ventral-lateral aspect of the neck and positioning the generator above (latero-dorsal to latero-ventral oblique) is easier to conceptualize the position of the articular process joints within the neck. However, if it is preferred, a latero-ventral to latero-dorsal oblique may be taken with the same results. The optimal angle (away from horizontal lateral) for obtaining properly positioned oblique radiographs ranges between 50–55° for C4–5 and 45–55° for C5–6 and C6–7, while remaining perpendicular to the sagittal plane (Fig. 2).\textsuperscript{2} The exposure variables (kV and mAs) are typically identical to those used for standard lateral projections; however, adjustments may be necessary on a case by case basis.\textsuperscript{2} Oblique radiographs are taken from both sides of the horse, so that the left and right articular process joints are each imaged in longitudinal and transverse planes. A minimum of one marker should be placed to note the left and/or right side of the plate. Depending on cassette size, two or three vertebral bodies will usually be visible on the radiograph. When three vertebral bodies are visible, the vertebra can be identified without additional markers or labeling by using the distinct shape of either the C2 (spinous process) or C6 vertebrae (ventral lamina). If one of

Fig. 3. A, An oblique radiograph centered on the C5–6 joint space. The location can be identified based on the unique characteristic appearance of the C6 transverse process. There are two markers to identify the left and right side of the vertebra. The axial and abaxial margins of the left (dorsally located) articular processes are outlined with a solid white line. The right caudal C5 articular process (white asterisk), right cranial C6 articular process (black asterisk), and their associated periarticular margins (dashed lines) are located ventrally on the image, resulting in the right articular process joint being superimposed and bisecting the intervertebral disc space (double dashed lines). B, A corresponding anatomy photograph, taken at an oblique angle from the dorsal aspect of the bones, at the same angle as the radiograph in A demonstrates the position of the articular processes and their periarticular margins in correlation to the appearance on the radiograph.

Fig. 4. A, In this oblique projection of the cervical spine at the level of C5–6, the ventral articular process joint is not centered over the intervertebral disc space. Instead, it is superimposed with the dorsal aspect of the space, meaning the radiograph obliquity is too shallow (i.e., too close to a lateral projection and not enough obliquity). As a result, the joint margins, particularly in the cranial aspect of the joint, are indistinct. B, The articular process joint space (white dashed lines) and intervertebral disc space (black dashed lines) are outlined. To obtain a more correct oblique radiograph, the angle of the x-ray beam should be increased or moved further away from lateral, which will move the ventral articular process joint further ventral to bisect the intervertebral disc space. The arrow demonstrates the direction the ventral joint will move when the angle is corrected.
these is present, then the adjacent vertebrae can be positively identified, and if neither of these are present, the radiograph must be of C3–C5. If the cassette size will only accommodate two vertebrae, an additional marker or labeling is required to identify the vertebral bodies. Anatomic landmarks (C2 and C6) and/or external markers are used to ensure all vertebrae and corresponding articular process joints are properly imaged from both sides. Even when multiple joints are visible in one image, due to beam divergence, the centered joint will be best visualized, while the joints at the periphery may not be positioned adequately to be properly evaluated. As a result, several radiographs may be required to place each vertebral articulation in the center of the cassette. Besides positioning, radiographs are also evaluated for adequate penetration, particularly at the level of C6–7.

If the cassette is held ventrally (latero-dorsal to latero-ventral oblique), the dorsal articular process joint in the image will be the joint on the side of the cassette and longitudinal/perpendicular to the joint space, while the ventral joint will be the “near” joint and transverse/parallel to the joint space. A properly positioned oblique radiograph will result in the ventral articular process joint being superimposed and bisecting the intervertebral disc space. The disc space should also bisect the articular process joint (Fig. 3). If the ventral joint is not bisecting the intervertebral disc space and is instead close to the dorsal joint, the radiograph is too close to lateral projection (angle of obliquity not steep enough), and

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**Fig. 5.** A. The dorsal to ventral obliquity is acceptable in this radiograph; however, the ventral articular process joint is superimposed over the cranial aspect of the vertebral body instead of the intervertebral disc space. This is a result of the x-ray beam not being perpendicular to the sagittal plane. B. The articular process joint space (white dashed lines) and intervertebral disc space (black dashed lines) are outlined. The dorsal articular process joint space (solid white line) is not directly in line with the ventral joint space. To correct the positioning of this radiograph, the ventral articular process joint is moved more cranial (in the direction of the white arrow) to where it bisects the intervertebral disc space. The x-ray beam should be angled in a more caudal to cranial direction to be perpendicular to the sagittal plane.

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**Fig. 6.** A. Focal discontinuity in the ventral cortex of a transverse process of the C5 vertebra (arrow) is noted on the standard lateral projection, indicating a fracture. B. On the oblique projection, the fracture can be identified affecting the right transverse process, and the ventral and dorsal extents of the fracture (arrows) can be better assessed.
the angle should be increased (Fig. 4). If the intervertebral disc space is not bisected by the ventral articular process joint, the radiograph is not perpendicular to the sagittal plane. When the ventral joint is caudal to the intervertebral disc space, the x-ray beam should be oriented more caudal to cranial to bring the articular process joint in line with the intervertebral disc space. If the ventral joint is cranial to the intervertebral disc space, the opposite correction should be made (Fig. 5).

Once the radiograph study is completed with proper technique and adequate views, the anatomic features of the cervical spine should be evaluated for abnormalities. Regarding the articular processes, an assessment of the periarticular margins, joint space, subchondral bone, and trabecular bone should be performed. The subchondral bone plate of the articular processes should be uniform in density and thickness, with distinct delineation from the adjacent trabecular bone.

3. Results
The dorsally located articular process joint is evaluated for osseous proliferation along the axial and
Fig. 8. There are prominent abnormalities affecting the articular process joint or joints at C6–7 on the lateral radiograph of this horse (A, arrowheads). However, it is not clear whether the findings noted on the lateral view are affecting the left and/or right articular processes. B, C, On the corresponding oblique projections, the osseous remodeling is noted to be markedly more pronounced in left articular processes more than the right. A component of the proliferation represents enthesopathy at the joint capsule attachments and/or fascial plane attachments away from the periarticular margins (B and C, black arrows). Arthrosis of the articular process joints is identified as osteophytosis along the margins on the oblique views (B and C, white arrows) that changes the normal shape of the joint margins. Also identified in this case are changes affecting the subchondral and trabecular bone of the articular process joints. The subchondral bone margins of the articular processes are undulating, with trabecular bone sclerosis (asterisk) present in the caudal facet of the C6 vertebra overlying a region of subchondral bone loss. In comparison, the horse in image D has normal periarticular margins.
abaxial margins. Periarticular margins and the articular surfaces, including assessment of the subchondral bone and adjacent trabecular bone reactions, can be best assessed in the ventrally located articular process joint. Fractures, osseous cyst-like lesions, and osteochondral lesions may be identified on the longitudinal or transverse image of the joint, or both, depending on their location. For abnormalities previously identified on standard lateral projections, the oblique view can differentiate whether only the left or right articular process joint is affected. This may be particularly important for unilateral abnormalities where treatment can be focused on the site of concern, for example intra-articular corticosteroid treatment or arthroscopic removal of articular process fragments.

In the authors’ experience, oblique radiographs have provided additional beneficial information in cases with fractures of the articular and transverse processes, periarticular osteophytosis, or other osseous remodeling along the cranial and caudal margins that are not visible on lateral projections, and differentiation of arthrosis from joint capsule enthesopathy. Depending on the fracture line orientation, a linear lucency with discontinuity of the bone may be visible on all projections, or easily missed on some while more obvious on others. In addition, multiple views can provide information on the configuration of the fracture and whether it involves the articular surface (Figs. 6 and 7). On lateral projections, the periarticular change characteristic of arthrosis can be difficult to distinguish from enthesopathy or other nonperiarticular change because the periarticular margins are superimposed over the adjacent bone (Fig. 8). Oblique radiographs allow identification of periarticular osseous proliferation altering the margins of the articular process joints, which can be sharply marginated or can create large, rounded periarticular margins (Fig. 9). Subchondral bone loss can be identified on oblique radiographs in the ventrally located articular process joint and is characterized by discontinuity in the density of the subchondral bone plate or undulation of the margin. Trabecular bone remodeling, often associated with abnormalities affecting the subchondral bone, is radiographically apparent as sclerosis or densification (Fig. 9). Osseous cyst-like lesions are often best or sometimes only identified on the dorsally located articular process joints, likely due to the superimposition of the vertebral body over the ventral articular process joint. However, when osseous cyst-like lesions are only identified in an articular process when it is the dorsally located articular process and not visible when ventrally located on the opposite oblique, it is not possible to determine if they are articular or within the trabecular bone (Fig. 10).

4. Discussion
Obtaining oblique radiographs increases the visibility of certain abnormalities in the cervical spine, particularly those affecting the articular process joints. Clinically, this is important for recognition of abnormalities that may not be apparent on standard lateral views. Furthermore, additional information and more accurate characterization of abnormalities identified on standard lateral views are possible with oblique radiographs. Removing the superimposition of the articular process joints and orienting based on the joint space is more in line with protocols used for other joints and provides more information because the bones are three-dimensional structures.

Proper radiographic positioning is paramount to achieve reliable information for oblique projections. Variation in the angles necessary to create properly positioned radiographs, identified with the bisection of the ventral articular process joint and the intervertebral disc space, is influenced by the position of the head and the neck. However, with continued practice and adjustment based on acquired images, the proper angle for the x-ray beam can be quickly determined, and consistent quality images can be achieved. Although the bisection of the intervertebral disc space and ventral articular process joint is considered ideal and is a guideline that will produce consistent results, there are cases, such as fractures, where the ideal positioning for visualization of the
abnormality may be different. In these cases, alterations of the angle with multiple different angles may be necessary to achieve an image that best characterizes the fracture line or other abnormality and relationship with the joint and articular surfaces.

Fig. 10. There is an osseous cyst-like lesion identified overlying the dorsal articular processes (arrows). This finding could not be identified on the lateral projection or the opposite oblique. Because it is only identified when it is overlying the dorsally located articular processes and not visible when ventrally located on the opposite oblique, it is not possible to determine if it is articular or within the trabecular bone. Further imaging with repeat oblique radiographs may allow the cyst to be identified on the opposite oblique if technique is considered a factor in the inability to identify the abnormality.

Drawbacks to performing oblique radiographs of the cervical spine include increased difficulty in acquiring adequate positioning, increased time for acquiring a full study, and added cost to the client. The benefits outweigh these technical considerations, as they allow better visualization of the joint space and periarticular margins. Including standard lateral views with the oblique views results in three orthogonal projections, which may increase the identification of abnormalities. The addition of oblique radiographs from both sides of the horse at the recommended angle of obliquity results in radiographs that demonstrate a clear joint space and periarticular margins.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.

References
Radiographic and Ultrasonographic Findings of the Caudal Cervical Region in 105 Warmblood Jumpers

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Evidence of mild osteoarthritis (OA) and joint effusion at the caudal cervical articular process joints was a relatively common finding in performing and sound jumpers independently of their age. Authors’ address: University of California-Davis, School of Veterinary Medicine, 1 Shields Ave., Davis, CA 95616; e-mail: pespinosa@ucdavis.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Cervical osteoarthritis (OA) in horses has been documented as a source of pain, poor performance, and lameness. The current study aimed to assess the prevalence of cervical OA and its correlation with ultrasound findings and age.

2. Materials and Methods
Warmblood jumpers free of lameness or neurologic disorders were selected for this study. The range of motion of the neck was subjectively assessed. Lateral to lateral views were taken at C4–C5, C5–C6, and C6–C7. An ultrasound of the cervical articular process joints was performed on a transverse plane. The presence of cervical OA was recorded and graded based on the radiographs. According to the ultrasound results, the presence of joint effusion or thickening of the joint capsule were documented.

3. Results
One hundred and five horses were included (mean age = 10.3 years [SD ± 2.8]). The C6–C7 cervical articular process joints were most commonly affected by OA, followed by C5–C6 and C4–C5. Radiographic signs of OA at C6–C7 were evident in 46 horses (mild OA = 22 horses [21%]; moderate to severe OA = 24 horses [23%]). At C6–C7, mild joint effusion was visible on the ultrasound in 37 cases (35%) and mild capsulitis was detected in 36 horses (34%). Statistically, there was no association between age and neck range of motion with the presence of OA, joint effusion, or capsulitis.

4. Discussion
This study showed that mild OA of the caudal cervical region is not rare in performing sound warmblood jumpers. Our results could guide veterinarians when

Research Abstract—for more information, contact the corresponding author

NOTES
evaluating asymptomatic horses such in pre-purchase radiographic examinations.

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
Ultrasonographic Diagnosis of Humeral Stress Fractures in Racehorses

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Ultrasound is useful to identify humeral stress fractures in racehorses and can be utilized alongside radiography to monitor healing. Authors’ addresses: Department of Surgical & Radiological Sciences (Vaughan, Spriet, Galuppo), and Department of Anatomy, Physiology and Cell Biology (Stover), University of California–Davis School of Veterinary Medicine, One Shields Avenue, Davis, CA 95616; Veterinary Healing Center of EDH, El Dorado Hills, CA 95762 (McKerney); PO Box 321, Pescadero, CA 94060 (Wollenberger); PO Box 35, Belmont, CA 94002 (Cloninger); e-mail: mevaughan@ucdavis.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Humeral stress fractures are well described in the racing population and can progress to catastrophic fracture if unrecognized. Associated lameness ranges from mild to severe, often improving rapidly over the first 24 hours. Nuclear scintigraphy remains the gold standard diagnostic but is limited by accessibility and cost. Radiographic findings are inconsistent until sufficient bone remodeling occurs. The use of ultrasound to diagnose humeral stress fractures has not previously been described.

2. Materials and Methods
Five horses suspected of stress fracture presented for humeral ultrasound between June 2013–February 2018. Clinical, ultrasonographic, radiographic and/or scintigraphic findings are described.

3. Results
Seven fractures were identified in 5 Thoroughbred racehorses ranging in age from 3–4 years. Horses developed acute severe lameness after returning to the racetrack 3–12 months following layup for a separate injury. Humeral stress fractures were bilateral (2), unilaterally right (2), or left (1). Ultrasound revealed a step defect (3), callus/roughening (7), and/or an abnormally convex contour of the caudoproximal humerus (7). Radiographs revealed periosteal and/or endosteal proliferation of the caudoproximal cortex (7). Radiopharmaceutical uptake of the caudoproximal humerus was seen on scintigraphy. (3) Serial recheck radiography and ultrasound (2) revealed progressive improvement. Horses remain convalescent (2), returned to intended use as racing/riding horses (2), and were retired (1).
4. Conclusion
Ultrasound is a useful, economical screening tool to identify humeral stress fractures and can be used with radiography to monitor healing. Affected horses can return to racing following appropriate rehabilitation.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

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The Authors have no conflicts of interest.
How to Use and Interpret Molecular Markers to Determine Viability of *Streptococcus equi* subspecies *equi*, Agent of Strangles

Nicola Pusterla, DVM, PhD, DACVIM*; and Samantha Mapes, MS

**1. Introduction**

*Streptococcus equi* subspecies *equi* (*S. equi*) causes strangles, a highly contagious upper respiratory tract disease with a worldwide occurrence. The clinical presentation of strangles is fairly characteristic and includes lethargy, anorexia, fever, purulent nasal discharge, and peripheral lymphadenopathy with abscess formation. Complications associated with strangles include metastatic spread and various immune-mediated conditions (purpura hemorrhagica, immune-mediated nephropathy, and myopathy). Laboratory support of strangles requires the detection of *S. equi* by microbiological culture or molecular detection from upper respiratory tract secretions or lymph node aspirates. According to the 2018 American College of Veterinary Internal Medicine consensus statement on *S. equi* infection in horses, culture is no longer valid as the gold standard and has been supplanted by quantitative real-time PCR (qPCR). Reasons for failure to identify *S. equi* by microbiological culture generally relate to low bacterial shedding, variation in anatomical sample location, and potential overgrowth with other beta-hemolytic bacteria, in particular *S. equi* subspecies *zoopneumoniae* (*S. zooepidemicus*). The increasing application of qPCR for the molecular detection of *S. equi* in practice settings has presented new dilemmas with regard to how test results are interpreted and used by both equine practitioners and regulatory veterinarians because routine qPCR assays are unable to differentiate between viable streptococcal organisms from nonviable cells or from free nucleic acids in biological samples. This paper will discuss the use and interpretation of molecular markers for *S. equi* viability in biological samples from horses with strangles.

**2. Materials and Methods**

Samples, Nucleic Acid Purification, and qPCR for *S. equi*

Biological samples (nasal/nasopharyngeal secretions, guttural pouch lavage fluid samples, lymph node aspirates) were collected from horses with suspected *S. equi* infection. The horses either presented to the authors’ referring hospital or biological samples were collected by field veterinarians and submitted to the authors’ diagnostic laboratory. All biological samples were processed for nucleic acid purification by using an automated nucleic acid
extraction system" according to the manufacturer’s recommendations. Total RNA was purified from the biological samples as follows: 20 μl of each freshly extracted nucleic acid sample (containing genomic DNA [gDNA] and total RNA) was digested with DNase for 60 minutes at 37°C to remove gDNA. DNase was inactivated at 95°C for 5 minutes. Complementary DNA (cDNA) from each sample was synthesized using 50 U SuperScript III b in a 40-μl final volume containing 50 mM Tris-HCl (pH 8.3), 50 mM KCl, 8 mM MgCl2, 0.5 mM dNTPs, 40 μl RNAsin, 0.5 mM dithiothreitol, and 600 ng random hexadeoxyribonucleotide [pd(N)6] primers (random hexamers). The reaction was performed at 50°C for 60 minutes. After inactivation at 95°C for 5 minutes, the reaction volume was adjusted to 100 μl with nuclease-free water. Nucleic acids (gDNA and cDNA) were assayed for the presence of the SeM gene of S. equi by using a previously reported qPCR assay. 7

Molecular Surrogates for Viability of S. equi
Three different approaches were used to determine molecular surrogates for viability. The first approach measured absolute quantitation of the target gene (SeM) at the gDNA level. Absolute quantitation of the SeM gene of S. equi was performed using a standard curve for the SeM gene, and the results were expressed as number of SeM target genes per microliter of gDNA. The rationale behind this approach was that a biological sample with high SeM target genes would likely represent viable S. equi. The second approach determined the presence or absence of messenger RNA (mRNA) transcripts for the SeM gene of S. equi at the cDNA level. The detection of bacterial mRNA has been established as a molecular viability marker due to its short half-life. 8, 9 The third approach compared the absolute quantitation of the SeM gene at the gDNA level between a preincubated sample and the same sample following an incubation step of 24 hours in a selective tryptic soy broth. 5 The rationale of that approach was based on viability being associated with an increase in absolute number of SeM target genes for S. equi between the pre- and post-enriched sample. Furthermore, each biological sample was initially tested according to laboratory standards for traditional microbiological culture. Post-enrichment samples were not subjected to traditional microbiological culture.

3. Results
A total of 30 biological samples were available for culture and molecular testing. Fifteen samples grew S. equi, while the additional 15 samples had either no growth or grew S. zooepidemicus. A total of 24 samples tested qPCR-positive for the SeM gene of S. equi. These included 15 S. equi culture-positive and 9 S. equi culture-negative samples (Table 1). Six samples tested qPCR-negative for the SeM gene of S. equi, all of which also yielded negative culture results for S. equi.

There was a significant difference in absolute quantitation at the gDNA level for the SeM gene of S. equi between qPCR-positive/culture-positive samples and qPCR-positive/culture-negative samples (Exact Kruskal-Wallis test, P < 0.01; Fig. 1). Using a receiver operating characteristic curve, biological samples with SeM gene copies of >14,748/μl showed 78% sensitivity and 80% specificity with successful microbiological culture. However, at this threshold, 22% of the culture-negative samples still yielded qPCR-positive results for the SeM gene. Furthermore, 20% of the culture- and qPCR-positive samples for S. equi had values of the SeM gene below 14,748 genes/μl.

SeM gene transcripts for S. equi at the cDNA level were found in all 15 culture-positive/gDNA qPCR-positive samples in 3 out of the 9 culture-negative/gDNA qPCR-positive samples and in 0 out of the 6 culture-negative/gDNA qPCR-negative samples.

Incubation of biological samples in tryptic soy broth for 24 hours and testing by qPCR of pre- and postincubation aliquots were performed for 13 samples. Four of these samples grew S. equi in the pre-enrichment samples, while the remaining 9 samples had either no growth or grew S. zooepi-
Absolute quantitation by qPCR for the SeM gene of S. equi at the gDNA level was significantly associated with cultivability. Eighty percent of S. equi culture-positive samples yielded absolute SeM target genes of >14,748/μl. The sensitivity and specificity of such a laboratory-specific threshold is, however, insufficient to reliably classify the viability of S. equi. The half-life of bacterial mRNA has been shown to be short for most bacteria, implying that bacterial viability goes hand in hand with the production of mRNA molecules.8,9,11 All S. equi culture-positive samples had detectable mRNA for the SeM gene, and 33% of S. equi culture-negative/qPCR-positive gDNA samples had detectable SeM gene transcripts. The inherent instability of mRNA, coupled with variability in sample collection, shipment, storage, sample processing, and presence of biological inhibitors can negatively influence its detection by qPCR. In order for this strategy to become established in the molecular diagnostic field of S. equi, commercially available RNA stabilizers need to be added to the biological samples shortly after their collection.5,6 However, this approach may not be presently practical or cost effective for the equine practitioner. The comparison of absolute quantitation for the SeM gene of S. equi between the original sample and the same sample following a 24-hour enrichment step showed promising results. This approach allowed viable S. equi to resuscitate and regrow later when the environmental conditions became more favorable. Six out of 7 S. equi qPCR-positive pre-enriched samples showed an increase in absolute quantitation of SeM target genes in the post-enriched samples, reflecting active growth. A similar approach is routinely used in the detection of Salmonella spp. from clinical and environmental samples.10

In conclusion, conventional culture methods for the detection of S. equi are time consuming and
unreliable, especially when bacteria enter an uncultivable life stage. For this reason, culture is no longer considered as the gold standard and has been supplanted by qPCR in recent years. Modern molecular approaches, such as absolute quantitation and detection of gene transcripts, can be successfully used in characterizing the viability of *S. equi* in biological samples. This information is pertinent for case management and preventing the spread of *S. equi*.

**Acknowledgments**

**Declaration of Ethics**

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

**Conflict of Interest**

The Authors have no conflicts of interest.

**References and Footnotes**


CAS-1820 X-tractor Gene, Corbett Life Science, Sydney, Australia.

SuperScript III, Invitrogen, Carlsbad, CA 92008.

Tryptic Soy Broth, Teknova, Hollister, CA 95023.

RNAlater, ThermoFisher Scientific, Waltham, MA 02451.
How to Use Transthoracic Ultrasonography to Identify Pulmonary Disease

Michelle Henry Barton, DVM, PhD, DACVIM

In addition to a complete physical examination, transthoracic ultrasonography is a fast and effective way to screen for pulmonary disease in either a hospital or field setting and is more sensitive than radiography for the detection of superficial consolidation. The greatest limitation of thoracic ultrasonography is that normal aerated lung precludes detection of deeper lesions. Thus, the absence of significant findings via transthoracic ultrasonography does not preclude the diagnosis of pulmonary disease, and additional diagnostics may be warranted such as a transtracheal wash, bronchoalveolar lavage, or thoracic radiography. Author’s address: University of Georgia, Athens, GA 30602; e-mail: barnonmh@uga.edu. © 2018 AAEP.

1. Introduction
Ultrasonography is a safe, affordable, and convenient technique for investigating peripheral lung disease. The greatest limitation of thoracic ultrasonography is that normal aerated peripheral lung precludes detection of deeper lesions. The purpose of this presentation is to use computer-generated 3D interactive Quicktime virtual reality (QTVR) movies to review and explain normal and abnormal pulmonary ultrasonography in horses. Although transthoracic ultrasonography is not a new procedure, the QTVR movies created for this presentation are original and unique and, thus, offer a novel method to both review and teach transthoracic ultrasonography.

2. Materials and Methods
The lungs can be scanned with just about any transducer, but high frequency transducers (>7.5 MHz) set to a depth of 4–8 cm provide the best detail. In most situations, soaking of the hair with warm water or isopropyl alcohol over the areas to be scanned is sufficient. However, in obese or heavily coated horses, clipping of the hair and use of coupling gel may be needed. Smaller footprint probes facilitate scanning in between ribs and can range from sector to straight or linear array transducers. A systematic approach should be used by scanning from the dorsal-most aspect of each intercostal space to its ventral-most aspect to the diaphragm, moving either cranially or caudally, intercostal to intercostal space, in the transverse (perpendicular to the spine) and slightly oblique plane as dictated by the ribs. Slowly moving the probe down each intercostal space allows the lungs to be visualized during both inspiration and expiration and may facilitate identification of subtle lesions that are only seen when the lung moves out from behind a rib or into the plane of imaging. Both sides of the thorax should be scanned from the right 3rd or the left 4th to the 15th to 16th intercostal spaces. Care must be taken to stay within the intercostal space, as the ribs will impede ultrasound penetration and will generate an acoustic shadow (anechoic area distal to the rib surface created by sound absorption). The
lungs may also be scanned in the dorsal plane that is parallel to the spine; however, impedance of the ribs limits viewing and, thus, it is more tedious to perform.

3. Results

Normal Anatomy

The lungs of the horse are considerably simpler than most other species in that they are not clearly divided into lobes by deep interlobular fissures (Fig. 1). However, they are paired as a left and right lung, with a small medially located accessory lobe that is associated with the right lung. Both the left and right lungs are separated in terminology only into the apical or cranial lobe and the diaphragmatic or caudal lobe, as defined by the cardiac notch. On the left, the cardiac notch of the lung is adjacent to the left third to sixth intercostal spaces and on the right, from the right third to fourth intercostal spaces. Thus, in the areas of the cardiac notches of the lung, the pericardium is in direct contact with the parietal pleura.

Ultrasonographically, the skin, subcutaneous fat, and intercostal muscles will be seen immediately adjacent to the footprint of the transducer (Fig. 2). They transmit sound waves well and do not generate artifacts. The interface between the pleural surface of the lung and the aerated lung deep to it will appear as a straight hyperechoic line. This hyperechoic line is compromised of the visceral pleura and can be seen sliding back and forth when the horse breathes, as the visceral surface of the lungs moves adjacent to the parietal pleura of the thoracic wall (Fig. 2). The characteristic “gliding line” is the hallmark of normal aerated lung. With the expectation that normal lung primarily contains air, which is a great reflector of ultrasound waves, normal aerated peripheral lung casts a relatively “boring” and uniform acoustic gas shadow, with the additional characteristic artifact of equidistant reverberation echoes that appear as parallel hyperechoic lines that are also called “A lines.” “A lines” occur when sound waves bounce back and forth (echo) between the transducer and the lung surface. Each subsequent reverberation of sound waves takes longer to return to the probe and, thus, appear as a hyperechoic horizontal line deeper and deeper to the initial intercostal muscle to lung interface (Fig. 3). The deeper “A lines” are more distorted than the superficial ones. When over a rib, the density of the bone reflects the sound waves and scatters and blocks further transmission. A hyperechoic curved (rib surface) line will appear in the near field within the muscle. Because ultrasound waves cannot penetrate beyond the rib surface, deep to this curved hyperechoic rib surface is a dark acoustic shadow that continues to the edge of the viewing screen.

![Fig. 1. A, Normal right-sided anatomy of the lungs. B, Normal left-sided anatomy of the lungs.](image1)

![Fig. 2. A, Virtual reality image of sonography of lung at the left 10th intercostal space. The red arrow marks the visceral pleural surface of aerated lung. B, An ultrasound image obtained of the left 10th intercostal space. The red arrow marks the hyperechoic line at the peripheral margin of normal aerated lung at the visceral pleural surface. The blue line marks intercostal muscles. Dorsal is to the left of the image. The image was obtained using a 12-MHz linear probe set to a depth of 6 cm.](image2)
The second artifact that is created by normal aerated lung is “B lines,” often referred to as “comet tails.” These are discrete vertical lines that originate from the pleural surface and move with the lung. Minute areas of fluid accumulation create comet tail artifacts in normal peripheral lung (Fig. 4). The ultrasound waves are transmitted through these small areas deep to the pleural surface. When the transmitted sounds reach the next interface of air in the lung, it is highly reflective and creates a discrete acoustic shadow that resembles the tail of a comet. As an artifact in normal lung, comet tails are most commonly seen in the dependent lung and the acoustic shadow usually fades long before reaching the edge of the screen. In people, less than three comet tail artifacts are expected at each intercostal space.

Abnormal Findings

Comet tails that appear dorsally or extend deep to the edge of the viewing field are likely pathologic and are generated by the presence of minute peripheral areas of nonaerated lung superficial to an aerated lung interface (Fig. 4). The sound may be transmitted past the pleural surface by fluid (edema, mucus), cellular infiltrate (leukocytes, neoplastic cells), or fibrosis. Comet tail artifacts are nonspecific to the etiology, as they can be seen with many disease states. Be mindful that mild comet tailing can be present in the dependent lung fields of normal patients.

Consolidation occurs when fluid or infiltrate (edema, pus, mucus, blood, neoplastic cells) accumulate in alveoli and, ultrasonographically, the affected area appears hypoechoic relative to surrounding aerated lung (Fig. 6). Often, consolidated lung is referred to as “hepatized” lung, as it appears acoustically more like liver than lung. Areas of consolidation are frequently dependent, often fairly discrete, highly variable in shape and size, and typically retain the normal shape of the lung. Small areas of consolidation may only be identified during expiration. Large areas of consolidation often have deep irregular hyperechoic borders that mark the interface with aerated lung. Larger areas of consolidated lung may have variable-sized scattered echogenic foci that represent focal areas of residual air within the predominantly consolidated lung. Air bronchograms, or air within bronchi within areas of consolidation, appear as distinct hyperechoic linear gas echoes that are easiest to detect when scanning parallel to the long axis of the bronchus. Fluid bronchograms, or fluid within bronchi, appear as hypoechoic linear structures that widen with convergence toward the hilus and are flanked on each side with hyperechoic linear walls of the bronchi (Fig. 7). The finding of pinpoint hyperechoic areas generating acoustic shadows within areas of consolidation is consistent with an anaerobic infection. Consolidation is most commonly identified in the dependent lung fields, especially on the right side. If pulmonary necrosis is present, air bronchograms will not be clearly identifiable within the area of consolidation. Pulmonary infarcts should be suspected if color flow Doppler shows abrupt disruption of blood flow in consolidated areas. Common differentials for consolidated lung include pneumonia and pulmonary edema.

Pulmonary abscesses appear as “space occupying” lesions with anechoic to mixed echogenicity. Abscesses appear similar to areas of consolidation but lack other evidence of normal lung tissue, such as the presence of air bronchograms.
as air or fluid bronchograms or vessels.\textsuperscript{2} Occasionally, the purulent material contained within an abscess can be seen as swirling, mixed echogenic material as the lungs move. Abscesses may appear encapsulated, have loculations of compartmentalization, and free gas foci. The latter is indicative of anaerobic infection and carries a guarded prognosis.\textsuperscript{5} Occasionally, in well-encapsulated abscesses, a dorsal gas to ventral pus interface can be detected within the abscess. Only peripherally located abscesses can be detected via ultrasonography (Fig. 8).

Other Space Occupying Lesions of the Lung
Other discrete hypoechoic "space-occupying" lesions of the lung include pulmonary neoplasia, granulomas, or pulmonary fibrosis\textsuperscript{6} (Fig. 9). Like pulmonary abscesses, these other space-occupying lesions vary in size and echogenicity, are devoid of other evidence of lung tissue, and are only detectable at the peripheral lung. Visceral pleural and subpleural fibrosis typically generate an increased number of comet tail artifacts and a scalloped appearance to the pleural surface (Fig. 4).\textsuperscript{2,3} Thoracic radiographs usually provide more global identification of the extent of space-occupying pulmonary lesions, but ultrasonography will provide precise location information that is more likely to facilitate guidance for biopsy.
4. Discussion

Transthoracic ultrasonography is a fast and effective way to screen for superficial pulmonary disease. Knowledge of normal thoracic anatomy and the general principles of ultrasonography are key elements that assist in deciphering normal from abnormal ultrasonographic pulmonary architecture. The greatest limitation of thoracic ultrasonography is the fact that normal aerated lung precludes detection of deeper lesions. Thus, the absence of significant findings via transthoracic ultrasonography does not preclude the diagnosis of pulmonary disease, and additional diagnostics may be warranted.

Acknowledgments

Declaration of Ethics

The Author has adhered to the Principles of Veterinary Medical Ethics of the AVMA.
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Conflicts of Interest
The Author has no conflicts of interest to disclose for this presentation other than the funding acknowledged above.

References
Frequency of Molecular Detection of Equine Coronavirus in Feces and Nasal Secretions in 277 Horses with Acute Onset of Fever

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The results of this study show that equine coronavirus infection should be considered in horses presenting with acute onset of fever, especially when nasal discharge is absent as one of the cardinal clinical signs. Authors’ addresses: Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California–Davis, Davis, CA 95616 (Pusterla, James, Mapes); Merck Animal Health, Summit, NJ 07940 (Bain); e-mail: npusterla@ucdavis.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Coronavirus infection in adult horses represents a diagnostic challenge considering that most horses only display general clinical signs with colic and diarrhea being present in less than 10% of affected cases. Equine practitioners often end up collecting nasal swabs rather than feces for the diagnostic workup of horses with acute onset of fever. Unfortunately, equine coronavirus (ECoV) is seldom detected in respiratory secretions of sick horses. Therefore, the objective of this study was to determine the frequency of detection of ECoV in nasal secretions and feces from horses with acute onset of fever.

2. Materials and Methods
A total of 277 horses with acute onset of fever were enrolled in this study. Feces were tested for ECoV and nasal secretions for common respiratory pathogens and ECoV by qPCR. Prevalence factors analyzed in this study included signalment, use, transportation history, number of affected horses, clinical signs and comorbidity between ECoV, and common respiratory pathogens.

3. Results and Discussion
The total number of horses testing qPCR positive for ECoV in feces was 20 (7.2%), 4 of which also tested qPCR positive for ECoV in nasal secretions. In the same population 9.0% of horses tested qPCR positive for equine herpesvirus (EHV)-4, 6.1% for equine influenza virus (EIV), 4.3% for S. equi ss. equi, 3.2% for equine rhinitis virus (ERV), and 0.7% for EHV-1. Draft horses, pleasure use, multiple horses affected on a premise, and lack of nasal discharge were significantly associated with ECoV qPCR-positive horses.
Acknowledgments
The study was partially supported by Merck Animal Health. The authors would like to thank all equine veterinarians who submitted samples for this study.

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
How to Use the Wireless Capsule Endoscopy Ambulatory Light-Based Imaging to Optimize Visualization of the Intestinal Mucosa

Renaud Leguillette, DVM, MSc, PhD, DACVIM, DACVSMR

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1. Introduction
The prevalence of gastrointestinal (GI) pathologies is high in horses, but their diagnosis can be challenging and requires access to expensive equipment. The size of the horse prevents exhaustive imaging of the GI tract. Abdominal radiography is extremely limited by the large amount of tissue that the beam of electromagnetic energy (X-ray) has to cross. Abdominal ultrasonography is limited by the large size of the abdomen and by the space occupied with large intestine, which also has a gas interface at its lumen. Specific ultrasonography probes and expertise are also often required to reach a diagnosis. Furthermore, endoscopic visualization of the GI tract requires a 3-meter-long (and expensive) gastroscope and still only allows for assessment of the stomach and pyloric region.1

Capsule endoscopy is a technology that has been used in human gastroenterology for over a decade.2 Capsule endoscopy records videos of the intestinal lumen as the capsule camera travels through the GI tract with the intestinal transit after ingestion by the patient. Some capsule cameras that transmit pictures via radiofrequency during intestinal transit have been tested in horses with mixed results, mainly because of the very short battery life or transmission problems.a3 Indeed, the large distance between the intraabdominal capsule and the receiver antennas made it challenging to obtain a good and continuous video signal. A new wireless capsule camerab has recently been commercialized for the veterinary market, more specifically, for canine cases. However, its use has been validated in horses and developed some protocols to optimize the visualization of the intestinal mucosa with the ALICAM.4 This capsule camera system has 4 cameras, an LED light source, and an on-board video recording system coupled to a motion detection system. The principle of this system is to have the camera move into the GI tract lumen and record videos of the intestinal mucosa while the horse is fully ambulatory and engaged in regular activities; the camera is then collected from the manure. The goals of this how-to paper are as follows: 1) to present protocols optimizing the quality of the capsule camera examination by maximizing the percentage of mucosa observed in the videos and 2) to describe the techniques used to recover the cameras.
2. Materials and Methods

The goal of the protocols is to obtain as many video frames as possible with a clear view of the intestinal mucosa, free of feed material. This percentage of visualization is the most important variable to increase the chances of observing GI tract mucosal lesions.

The capsule camera technique can be used on-farm and does not require hospitalization. However, it is important to take measures to recover all of the manure from the horse, and some methodological details are provided below. The author has used the technique while keeping horses in stalls as well as in small pens.

Preparation of the Horse for the Capsule Camera Examination

The horse should be kept in a stall before the capsule camera is administered, and all feed is withdrawn for 24 hours. Water access is removed for 12 hours before the camera administration. The horse is walked at least twice during this 24-hour period.

Insertion of the Camera

The camera can slide inside a large equine stomach tube (>10-mm diameter). Sedation is best avoided and only used if necessary. It is recommended to use a nasogastric pump to push the camera through the tube with 0.5 to 1 liter of water. Do not use any lubricant. A few pump strokes are enough and the usual technique should be used to ensure that the nasogastric tube delivered the camera and water in the stomach.

Feeding and Water Access

Water access and slow refeeding are started 3 hours and 12 hours, respectively, after the nasogastric intubation. The horse is then fed 4 times daily with hay only. The horse can be kept in a stall or in a small pen. Walking or exercising the horses did not improve the transit time of the camera and the examination results are better if the horse stays confined to a stall or small paddock.

Transit Time Before Recovery of the Camera

Prepare the barn staff and horse owner for a period of 2 to 10 days before the camera is recovered.

Recovery of the Camera

It is crucial to make sure that no manure is missed for the recovery of the camera. If the horses defecate while being moved from a stall to a pen, this manure must also be collected. We found that the easiest and most convenient technique is to collect all of the manure in large plastic bins over several days. We have used commercial manure recovery bags, but found that they are not necessary as long as the barn staff doing the husbandry is diligent about collecting all of the manure in the bins. The manure on top of the bins is inspected first visually, and, if the camera is not observed with the naked eye, radiographs are performed. We use at least 3 radiographic views per bin so that all the content can be examined. Radiographs can be performed on-farm every few days as the horse handlers are collecting the manure and labeling the bins. Digital radiography is the most convenient. The capsule camera will have a metal density and a pattern that is unique and typical on the radiographs. We found that many small metallic pieces could sometimes be found in the bins, but the shape of the camera capsule makes it easy to distinguish it from other metallic debris.

Capsule Camera Report

The capsule camera is shipped back to the manufacturer where the video is downloaded and interpreted. A report with detailed pictures of lesions and findings is provided.

3. Results

The author has performed more than 20 capsule camera examinations in adult horses, weanlings and a miniature donkey.

The capsule cameras usually record >35,000 frames for analysis. The recording time in the stomach is often <4 hours, followed by a small intestine recording time of 2 to 5 hours, followed by >10 hours of recording in the cecum, where the camera runs out of battery.

The capsule camera technique allows for a good examination of the glandular and pyloric areas of the stomach, where the mucosa can be seen with details in >33% of the video frames.

High-quality close-up images of the duodenal papilla are also usually obtained.

A great percentage (~40%) of the small intestine mucosa with its villi is also usually visualized when the above protocol is followed.

The mucosa in the area of the ileocecal junction is also usually well visualized.

The visualization of the cecal mucosa is poor (often <1%) and the mucosa of the colon was only barely seen in one case only.

The time for the camera to be excreted out in the manure varies from horse to horse. It can take up to 2 weeks before it is found in the manure. The delay is suspected to be due to retention of the capsule within the cecum.

Lesions observed include erosions, ulcerations, pinpoint and submucosal hemorrhage, dilated lacteals, as well as the presence of sand accumulation and parasites. Diagnoses of ulcerations, protein-losing enteropathy associated with lymphangiectasia, sand accumulation, and parasitism have been made with the capsule camera in our clinical cases.

4. Discussion

The capsule camera technique is a new technology that is safe to use in the equine. It can be used in horses, weanlings, and miniature donkeys. The technique is the only one so far allowing the record-
ing of intraluminal images of the GI tract aboral to the pyloric area. Capsule endoscopy is indicated in cases with serum hypoproteinemia, chronic colic cases, or for suspected intestinal neoplasia.

The following are pros of this technique:

- Provides excellent assessment of the intestinal mucosa in the pyloric area, small intestine, and ileocecal junction. Villi are seen in great detail. Increases the sensitivity and specificity for diagnosing pyloric and small intestinal pathologies.
- Very practical technique; can be done on-farm.
- Does not require investing in equipment.

The following are cons of this technique:

- No assessment of the cecal and large intestinal mucosa.
- Recovery of the capsule from the manure can take up to 2 weeks and requires some specific management on-farm.

Diagnosis of pyloric and small intestinal pathologies is challenging. The capsule camera allowed diagnosing intestinal lesions that would have been otherwise missed. It was useful in cases as simple as chronic sand ingestion or as complex as lymphangiectasia.

The capsule endoscopy is indicated in cases with serum hypoproteinemina, chronic colic cases or when an intestinal neoplasia is suspected. The author diagnosed lesions of the intestinal mucosa even when the small intestinal ultrasound examination did not reveal any abnormality.

The preparation of the patient following the above protocol is important; if feed is not withdrawn for long enough, feed material can obstruct good visualization of the mucosa. However, if feed is withdrawn for too long, motility is decreased too much for a good examination.

The challenge of the technique is clearly the recovery of the camera from the manure. Using manure collection bags (similar to the ones used for carriage shows) and they work well for a few days but can also induce some pressure points if they are not emptied frequently (they can become heavy). The most practical and successful approach is to collect the manure from the bedding or from the ground if the horse is in a small pen. Out of ~20 capsules administered, 2 cameras failed to be recovered, both from the same horse, when using a different preparation protocol. Manure collection and inspection, both visual and radiographic, ceased 2 weeks after capsule administration. It is possible that the camera was lost in the pen or that it was retained in the cecum of this horse. A collaborator took abdominal radiographs in a weanling and in a miniature donkey after 12 days and could visualize the capsule in the abdomen of these animals. The author has performed an abdominal ultrasound examination on a horse 3 days after the administration of a capsule and saw images compatible with a metallic round object of small size in some large intestine in the lower right abdomen (suggesting it was in the cecum). The author has not failed to recover cameras with the protocol described above.

Radiography of plastic bins containing the manure is the most practical way to identify and recover the camera. However, a simple visual inspection of the manure also recovered the camera in some cases.

In summary, the ALICAM capsule technique is safe to use in equids of all sizes, with low serum proteins or chronic abdominal discomfort. The technique provides excellent detailed visualization of the pyloric area of the stomach, of the small intestinal mucosa, and of the ileocecal junction. It does not provide visualization of the large intestinal mucosa. It is a practical technique on-farm but requires recovery of the camera from the manure, the timing of which is highly variable from horse to horse.

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Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References and Footnotes

5. Gibbard D. Assessment of capsule endoscopy technology as an imaging tool for the equine small intestine [thesis]. Guelph, ON, University of Guelph; 2015.
6. Ambulatory Light-Based Camera (ALICAM), Infinity Medical LLC, Redwood City, CA 94065.
1. Introduction

Fever of unknown origin (FUO) without a respiratory component is a frequent clinical presentation in horses. Multiple pathogens, both tick-borne and opportunistic bacterial pathogens, are likely to be involved as etiologic agents of FUO.

2. Materials and Methods

Areas known for a high prevalence of tick-borne diseases in humans were chosen to survey horses with FUO that have no signs of respiratory illness or other recognizable diseases. Blood samples and clinical parameters were obtained from 52 of these horses with matched controls from the same farm. An additional 23 febrile horses without matched controls were also included. Ticks were collected and tested by PCR from these farms. Using broadly targeted PCR amplification directed at conserved sequence regions of 16S and 18S rRNA, followed by high-throughput sequencing and metagenomic analysis, we compared blood from horses presenting with FUO with matched healthy controls from the same premises.

3. Results and Discussion

Of the 358 identifiable sequences that were significantly present in cases with fever vs. controls (p<0.05), 62 were from the genus *Ehrlichia* and 42 were from *Anaplasma*. The presence of multiple tick-borne pathogens was identified in two samples. As suspected by practitioners, this study confirmed that *A. phagocytophilum* is a common cause of FUO in these geographic areas.

Acknowledgment

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Declaration of Ethics

The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest

The Authors have no conflicts of interest.
Sarcocystis fayeri Infection Associated with Neuromuscular Disease in Horses

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Neuromuscular disease in some cases can be associated with Sarcocystis fayeri infection in muscle. Clinical manifestations can include muscle atrophy, weakness, stiffness, apparent muscle pain, undetermined gait deficits, and in some cases dysphagia. The assumption that S. fayeri in skeletal muscle is always an incidental finding might not be accurate in every case. Authors’ addresses: Department of Medicine (Aleman, Madigan); Department of Pathology, Microbiology, and Immunology (Shapiro, Sisó, Rejmanek, Aguilar, Conrad); The William R. Pritchard Veterinary Medical Teaching Hospital (Williams), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; e-mail: mraleman@ucdavis.edu. © 2018 AAEP.

1. Introduction

Sarcocystis fayeri-induced toxicity causing muscle and intestinal sarcocystosis has been reported in humans consuming raw horse meat.1,2 Clinical manifestations include intermittent or chronic myalgia, myositis, muscle wasting, arthralgia, fatigue, headache, bronchospasm, rashes, facial swelling, fever, cardiomyopathy, and glomerulonephritis.1 Sarcocysts in the skeletal muscle of equids has been commonly regarded as an incidental finding. However, there have been isolated case reports of muscle sarcocystosis and anecdotal descriptions of horses with unexplained gait deficits and neuromuscular disease of undetermined etiology responding to treatment with antiprotozoal drugs.3 Furthermore, experimental infection of S. fayeri in ponies produced clinical manifestations of disease in one study.4 Furthermore, the observation by one of the authors of encysted parasites in horses’ skeletal muscle with neuromuscular disease prompted the authors to investigate the prevalence and molecular characterization of Sarcocystis spp. infection in equids. Therefore, the objective of this study was to investigate the prevalence of sarcocysts in the skeletal muscle of horses with neuromuscular disease. This study was published in Neuromuscular Disorders 2016 and is modified here for AAEP Proceedings.5 Furthermore, additional relevant clinical information is provided here.

2. Materials and Methods

This study included equine skeletal muscle with evidence of encysted parasites within myofibers
sourced from two diagnostics laboratories from the authors’ institution. Owners’ consent was obtained to use muscle specimens for the study. Muscle biopsy specimens were collected because of suspected neuromuscular or muscle disease. The medical records of the selected horses were reviewed for a definitive diagnosis. Muscle specimens were processed according to each laboratory protocol. For a comparison of findings, healthy horses were used as controls. This study was approved by an Animal Care and Use Committee.

Muscle Biopsy

Muscle biopsy specimens were snap frozen in isopentane precooled in liquid nitrogen and stored at −80°C until further processing. Muscle specimens were routinely processed for histological and immunohistochemical analysis and evaluated under light microscopy. Myofibers were characterized by fiber type (1, 2A, 2B) through ATPase reaction at preincubation pH of 9.8, 4.6, and 4.3. The cross-sectional area of fiber types was determined using a total of 100 muscle fibers of each type in 3 random locations, for a total of 300 myofibers of each type. Only areas without artifacts and myofibers with distinct borders were measured. Immunohistochemistry to determine the type of inflammatory cells, if present, included clusters of differentiation (CD) for B-lymphocytes (CD20, CD79), T-lymphocytes (CD3, CD4, CD8), and macrophages (CD11c). Additional skeletal muscle specimens consisted of archived formalin-fixed paraffin-embedded blocks and glass slides routinely stained with hematoxylin and eosin.

Molecular Analysis

To determine the sarcocyst species, DNA was extracted from 15 muscle samples. Nucleic acids were extracted using the DNeasy blood and tissue kit.

Statistical Analysis

Descriptive statistics included mean, standard deviation, and range for all measurements. A Fisher’s exact test was used to test for an association between the presence of sarcocysts as well as the number of muscles with sarcocysts and state of health (diseased and healthy horses). An independent t-test was used to compare myofiber size from those with and without sarcocysts, and the number of sarcocysts per muscle specimen between horses with neuromuscular disease and controls. Statistical significance was set at P = 0.05.

3. Results

Encysted parasites in skeletal muscle were identified in a total of 50 equids: 35 equids with neuromuscular disease from one of the diagnostic laboratories and 15 horses with miscellaneous disorders from archived formalin-fixed samples. The control group consisted of 36 horses. Skeletal muscle from a total of 392 equids with neuromuscular disease were evaluated during the study period for a prevalence of 8.9%. Various breeds were represented, including Percheron, Quarter Horse, Thoroughbred, Arabian, Warmblood, Mustang, Paso Fino, and Icelandic pony. The mean and median age was 7 years old (range, 1–16 years of age). Diseased horses had signs compatible with multifocal or diffuse neuromuscular disease, such as weakness, short stride gait, and muscle atrophy (Fig. 1). Some horses also had muscle stiffness, fasciculations, and apparent pain upon palpation. Altered gait had an undetermined etiology, and ataxia was seen in 2 horses. Horses with dysphagia had swollen and apparently painful tongues. Of the 36 control horses, only 1 had a single encysted parasite for a prevalence of 2.7% within this control population.

Twenty of 35 horses had a complete blood cell count and serum biochemical profile done. Normocytic normochromic anemia (packed cell volume, 28–30%; reference range, 28–30%; range, 32–45%) was identified in 3 of 20 horses and eosinophilia in 5 of 20 (2.5–4.7% of total white blood cells). An elevation of muscle enzymes was observed in 13 of 20 horses: creatine kinase ranged 560–250,000 IU/L (reference range, 119–287 IU/L) and aspartate aminotransferase ranged 999–29,568 IU/L (reference range, 168–494 IU/L).

Although equine protozoal myeloencephalopathy (EPM) was not suspected in these horses based on neuroanatomical localization of neuromuscular disease, an immunofluorescent antibody test for S. neurona and Neospora hughesi antibodies was performed in 17 horses. Of these, 6 horses were negative for antibodies, 9 had low titers or below the cut-off value provided by the diagnostic laboratory at the authors’ institution, and 2 had titers above the cut-off value considered supportive of EPM. Two additional horses with clinically suspected EPM based on progressive multifocal asymmetrical central nervous disease had serum and CSF titers supportive of EPM (horse 1, S. neurona; horse 2, S. neurona, N. hughesi).

Fifty-one (83.6%) of 61 muscles from 35 equids with neuromuscular disease had encysted parasites, versus 1 (1.4%) of 72 muscles from 36 healthy horses (significant difference, P < 0.001). Based on histological findings, the horses were grouped into disease categories: noninflammatory myopathies (n = 18/35 horses), inflammatory myopathies (n = 4/35), neurogenic muscle atrophy (n = 2/35), and normal histology (n = 1/35). Noninflammatory myopathies included nonexertional rhabdomyolysis of undetermined cause, nutritional myodegeneration due to vitamin E and selenium deficiency, polysaccharide storage myopathy, vacuolar myopathy of undetermined cause, pituitary pars intermedia dysfunction, and malignant hyperthermia. Inflammatory myopathy consisted of myositis with a predominance of CD8+ T-lymphocytes with marked myonecrosis (Fig. 2). Myofibers containing sarcocysts were significantly larger than ones without parasites. Mo-
molecular testing identified *S. fayeri* as the parasite present in the skeletal muscle.

A subset of horses (n = 10/35) with sarcocystosis from this study were treated orally with 15% ponazuril (5 mg/kg, every 25 h) for 15–28 days. Clinical signs of weakness, stiffness, apparent pain on palpation, and gait deficits subsided within 15 days of treatment, and muscle mass returned to normal within 1–2 months (not published data). After the publication of this study, 12 additional horses with

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**Fig. 1.** Weakness is noted as a narrow-based stance of the horse: thoracic and pelvic limbs closer together and a lower carriage of head and neck. Notably, there is muscle atrophy, especially of the epaxial muscles (top line more visible).

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**Fig. 2.** Hematoxylin and eosin at 10×, formalin-fixed. Note 2 sarcocysts within myofibers (top right of figure) and inflammatory infiltrates consisting mainly of T-lymphocytes (CD8+ and CD4+ [left of figure], immunostaining not shown here). Calibration bar = 100 μm.
neuromuscular disease and sarcocystosis in the skeletal muscle were also treated orally with ponalurizl and similar resolutions of signs were observed, with all horses returning to normal physical activity (personal communication, 2017). In these horses, all other possible causes of neuromuscular disease were ruled out to the best ability of the authors and clinicians.

4. Discussion
Findings indicated that S. fayeri infection was common in young mature equids with neuromuscular disease. Horses with neuromuscular disease included myopathic, neurogenic, and mixed (myopathic and neurogenic) processes. The number of infected muscles and number of sarcocysts per muscle were significantly higher in diseased than in control horses. Sarcocystis fayeri has a high glycolytic metabolism and was predominantly found in low-oxidative highly glycolytic myofibers. Common clinical signs included muscle atrophy, weakness with or without apparent muscle pain, gait deficits of undetermined cause (lack of localization with nerve and intra-articular anesthetic block), and dysphagia in horses with involvement of the tongue and esophagus. Horses with myositis were lethargic, apparently in pain, stiff, and reluctant to move. Similar to humans, sarcocystosis and cardiomypathy can occur in horses. Similar clinical signs of progressive muscle wasting, weakness, and lethargy in horses with granulomas and eosinophilic and plasmacytic-lymphocytic myositis associated with Sarcocystis spp. have been reported by others. Although our study did not establish causality but a possible association (8.9% of cases) with neuromuscular disease was more consistent with neuromuscular disease and included clinical signs of weakness, stiffness, apparent pain on palpation, and gait deficits. This is in contrast with multifocal or focal asymmetrical central nervous disease with asymmetrical muscle atrophy observed in horses with EPM.

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA. The study was reviewed and approved by an Animal Care and Use protocol.

Conflict of Interest
The Authors have no conflicts of interest.

References and Footnotes

*Denby Blood and Tissue, Qiagen Group, Austin, TX.
15% Ponazuril, Marquis®, Merial, Inc., Duluth, GA 30096.
How to Effectively Supplement Horses with Vitamin E

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1. Introduction

Vitamin E (vitE) is an essential fat-soluble vitamin that is required for healthy neuromuscular function. VitE is actually a general term used to describe a family of eight naturally occurring closely related compounds.1 Alpha-tocopherol (α-TOH), specifically the natural RRR stereoisomer (RRR-α-TOH), is the most bioavailable and bioactive form in animal tissues due to preferential uptake by the liver.2 The major dietary source of vitE in horses is forage, optimally providing approximately 2,000 IU/day of natural α-TOH to grazing horses.3 However, the amount of fresh pasture available to horses is markedly decreasing and the amount of α-TOH in hay declines markedly with processing and storage.4 Commercial feeds usually provide α-TOH in the form of synthetic vitamin E, containing a mixture of eight isomers (dl-α-tocopherol [all-rac-α-tocopherol]), of which only one is identical to the natural isomer. This form of vitE is a less bioavailable formulation than natural α-TOH. Thus, many horses receive far less α-TOH than the dietary requirements of 1–2 IU/kg body weight set by the 2007 National Research Council.5

A deficiency of whole-body vitE is typically assessed by measuring serum concentrations of one component of vitE, α-TOH, with normal equine serum concentrations >2 μg/mL.2 Whether or not a deficiency of vitE has an impact on health depends on individual genetic factors, the temporal occurrence of deficiency during development, and the duration of deficiency (Table 1). If genetically susceptible foals are vitE deficient during the first year of life, they may develop equine neuroaxonal dystrophy/equine degenerative myeloencephalopathy (eNAD/EDM), a neurodegenerative disease characterized by a general proprioceptive ataxia. We have found that foals with eNAD/EDM have very low cerebrospinal fluid (CSF) α-TOH concentration.6 Older horses that have been vitE deficient for ≥18 months7 can develop equine motor neuron disease, resulting in clinical signs of weakness and neurogenic muscle atrophy.8 Some adult horses, potentially those with a shorter duration of vitE deficiency, have a vitE deficient myopathy and present with muscle weakness, low muscle α-TOH concentrations, and mitochondrial alterations in skeletal muscle but have no evidence of neurogenic atrophy.9
To correctly supplement vitE in the horse, the type and formulation of vitE supplements need to be considered.

Formulations

Natural vitE, RRR-α-TOH, is more bioavailable than synthetic vitE and, therefore, many equine supplements now strongly market the “natural” (i.e., RRR) form. The natural formulation is available as an esterified form (α-TOH acetate) to prolong shelf life (i.e., powder or pellet) or as a water-dispersible (i.e., liquid) formulation with higher biopotency (Table 2).

Dosage

Most studies of vitE supplementation have used healthy horses and assessed serum α-TOH rather than neuromuscular tissue concentrations. The absorption and metabolism of vitamin E in healthy horses may differ from that of horses with diseases associated with vitE deficiency. As a result, it is essential to measure serum α-TOH concentrations, monitor α-TOH concentrations, and adjust the dose in response to supplementation.

2. Materials and Methods

A step-wise process, based on the following points, is followed to effectively increase α-TOH concentrations. This is summarized in Fig. 1.

3. Results

The most rapid rise in serum α-TOH concentrations is obtained by providing natural-source liquid forms of α-TOH at 10 IU/kg body weight. The liquid formulation is 5–6 times more bioavailable than synthetic α-TOH acetate, and a 5000 IU dose/horse more than doubles serum vitE levels within 12 hr. Research into healthy horses with marginal or deficient serum α-TOH concentrations found that 14 days of water-dispersible natural α-TOH supplementation at 10,000 IU/horse/day significantly increased CSF α-TOH.

Many owners are reluctant to maintain horses on liquid supplementation long-term and, therefore, a switch to a powder or pelleted supplement is often desired. However, veterinarians should be aware that when horses are switched from the same dose of natural water-dispersible α-TOH to the powdered acetate formulation, a precipitous drop in serum α-TOH can occur. Based on our research, we propose that the best and most economical approach to supplementing deficient horses over time is to overlap treatment with the liquid and powder/pellet formulations and gradually withdrawing the liquid α-TOH, leading to a better steady state of serum α-TOH and higher tissue α-TOH concentrations of continued supplementation (Fig. 1).

If horses are deficient in α-TOH without signs of neuromuscular disease and owners find the water-dispersible formulation of α-TOH cost-prohibitive, supplementation can be started with 5000 IU/day of the natural powder/pelLETED α-TOH acetate. However, serum α-TOH concentrations are not expected to increase for at least 8–10 weeks by using this protocol.

4. Discussion

In our research, we have performed over 10 vitE supplementation trials by using various formulations in both healthy but vitE-insufficient horses and horses with specific neuromuscular diseases. We have demonstrated repeatable success when using an RRR-α-TOH liquid formulation for supplementation at the dosages discussed above. There were, however, a subset of horses that failed to respond to correctly supplemented α-TOH. These horses may have malabsorption due to inflammation.

<table>
<thead>
<tr>
<th>Type of Supplement</th>
<th>Form of VitE in Supplement</th>
<th>Bioavailability</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural vitE (liquid)</td>
<td>RRR-α-TOH</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Natural vitE (powder or pellet)</td>
<td>RRR-α-tocopheryl acetate</td>
<td>Intermediate</td>
<td>Intermediate</td>
</tr>
<tr>
<td>Synthetic vitE (powder or pellet)</td>
<td>All-rac α-tocopheryl acetate (all stereoisomers) or dl-α-tocopheryl acetate (RRR and SRR-stereoisomers)</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 1. Equine Neuromuscular Diseases Associated with VitE Deficiencies

<table>
<thead>
<tr>
<th>Disease</th>
<th>Age of onset</th>
<th>Clinical signs</th>
<th>Effect of treatment with vitamin E</th>
<th>EMND</th>
<th>eNAD/EDM</th>
<th>VEM</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMND</td>
<td>Adult; median age 10 years</td>
<td>Muscle wasting and fasciculation, abnormally low head carriage, prolonged recumbency</td>
<td>40% of cases improve, 40% stabilize but remain disfigured, 20% progress</td>
<td>Adult</td>
<td>Muscle wasting and fasciculation, abnormally low head carriage</td>
<td>6–12 months</td>
</tr>
</tbody>
</table>

Table 2. Forms of VitE Supplementation Available
from parasitic infections\textsuperscript{16} or another type of gastrointestinal inflammation. We are currently evaluating an injectable product for horses, but at this time, there is no approved injectable vitE product for horses that will effectively raise serum \( \alpha \)-TOH concentrations. The only Food and Drug Administration-approved product for horses, E-Se\textsuperscript{6}, will increase selenium concentrations but does not provide enough bioavailable \( \alpha \)-TOH to affect serum \( \alpha \)-TOH concentrations\textsuperscript{6}.

Although many nutrition companies tout their products as containing “natural vitE,” many have not been assessed in well designed clinical trials. For that reason, we recommend careful consideration of both product type and dose when targeting vitE supplementation in deficient horses. For large herds, the most cost-effective means of supplementing horses is to provide fresh pasture for at least 6 mo of the year. Where this is not an option, targeted supplementation as recommended here is advised. Assessing individual serum \( \alpha \)-TOH is paramount, as vitE metabolism differs widely from horse to horse\textsuperscript{2}.

Although vitE supplementation is generally considered safe, there is a risk of oversupplementation. Supplementation with vitE may alter drug metabolism and disposition, because, in humans, the same cytochrome isoforms that metabolize vitE metabolize >50\% of therapeutic drugs.\textsuperscript{17} The National Research Council has set the upper safe diet concentration at 20-IU/kg body weight based on the biopotency of synthetic \( \alpha \)-tocopherol (10,000 IU/500 kg horse). Above this level, coagulopathy and impaired bone mineralization have been reported\textsuperscript{5}. Therefore, the regular assessment of serum \( \alpha \)-TOH concentrations is highly recommended. Serum concentrations >4 \( \mu \)g/mL are too high and decreasing the dose is recommended in those horses.

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Declaration of Ethics
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Conflict of Interest
The Authors have no conflicts of interest.

References
Effects of a Dietary Supplement on Insulin and Adipokine Concentrations in Equine Metabolic Syndrome/Insulin Dysregulation

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Dietary supplementation with a synergistic polyphenol and amino acid blend including leucine had positive impacts on metabolic parameters in EMS/ID horses. Lowering insulin and increasing high-molecular-weight adiponectin could provide a clinical benefit by decreasing laminitis risk. Authors’ addresses: Department of Pathobiology and Diagnostic Investigation, Michigan State University College of Veterinary Medicine, East Lansing MI 48824 (Manfredi, Stapley); Kentucky Performance Products, LLC, 60 Thomas Lane, Versailles, KY 40383 (Nash); e-mail: manfred1@msu.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
High insulin concentrations are known to induce laminitis, so reduction of insulin concentrations in response to an oral challenge should decrease risk. In human studies, diets containing a polyphenol (resveratrol) led to improvements in insulin sensitivity. In rodents, resveratrol combined with leucine (L) allowed for a decrease in the amount of resveratrol used in the supplement to achieve similar clinical effects. The authors hypothesize a low dose of a synergistic polyphenol and amino acid blend including leucine (SPAAB/H11001L) supplement would improve metabolic health in horses with equine metabolic syndrome/insulin dysregulation (EMS/ID).

2. Materials and Methods
Fifteen EMS/ID horses received a high or low dose of SPAAB+L for 6 weeks. Insulin during an oral sugar test (OST), body condition score, weight, baseline high molecular weight (HMW) adiponectin, triglycerides, nonesterified fatty acids, and tumor necrosis factor (TNF)α were assessed pre- and post-supplementation via paired Student’s t-tests and a repeated measures mixed-model ANOVA (significant at P < .05).

3. Results
Post-supplementation, horses weighed significantly less, had significantly higher baseline HMW adiponectin concentrations, and lower insulin concentrations at the 60- and 75-minute OST time points. There were no differences noted between doses.

4. Discussion
Horses receiving either dose of SPAAB+L for 6 weeks showed decreased insulin concentrations in response to dynamic testing. Increased HMW adiponectin supports increasing insulin sensitivity post-supplementation.

Acknowledgments
This study was funded by Kentucky Performance Products.

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Delia Nash is an employee of Kentucky Performance Products.
The other Authors have no conflicts of interest.

Research Abstract—for more information, contact the corresponding author

NOTES
Effects of Magnesium with or without Boron on Headshaking Behavior in Horses with Trigeminal-Mediated Headshaking

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Horses with trigeminal-mediated headshaking suffer neuropathic pain, leading to poor quality of life and even euthanasia. Dietary supplementation providing a source of magnesium (grain) and additional magnesium with or without boron decreased headshaking behavior, when compared with diet consisting of hay only. Authors’ addresses: Department of Medicine and Epidemiology (Sheldon, Aleman, Costa, Madigan); Department of Population Health and Reproduction, School of Veterinary Medicine (Weich). University of California–Davis, Davis, CA 95616; Quinn Howey Racing, Fresno, CA 93704 (Howey); e-mail: sasheldon@ucdavis.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Horses with trigeminal-mediated headshaking have neuropathic pain, which manifests as sudden jerking of the head. There is anecdotal information that magnesium supplementation decreases headshaking behavior in some horses, but that has not been evaluated. Boron increases ionized magnesium in the blood. This study hypothesizes that magnesium and magnesium-boron supplementation will reduce headshaking behavior.

2. Materials and Methods
Twelve horses (six headshakers and six controls) received a hay diet and were randomized into three treatment groups: grain (G), grain with magnesium (M), and grain with magnesium-boron (MB), with a week washout of hay only between treatments. Headshaking behavior and blood parameters were assessed at baseline (hay only) and then after each week of supplementation.

3. Results
All three diet interventions (G, M, and MB) provided a source of magnesium and increased blood ionization and total magnesium and also caused changes in blood Ca\(^{2+}\), K\(^+\), Na\(^+\), Cl\(^-\), and HCO\(_3^-\). Groups M and MB further increased total and ionized magnesium when compared to group G. Horses receiving treatments (G, M, and MB) had a significant reduction in headshaking behavior when compared with unsupplemented hay diet.

4. Discussion
Horses receiving the G, M, and MB treatments had significant decreases in headshaking behavior.
Supplementation with magnesium or magnesium-boron should be considered in horses affected with headshaking.

Acknowledgments

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
Platinum Performance® provided oral magnesium and boron supplements and partial support for a graduate student.
Effects of Season on Morphometric Measurements and Insulin Responses to the Oral Sugar Test in Control vs Insulin Dysregulated Horses

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Season affects basal insulin and insulin responses to the oral sugar test in insulin-dysregulated horses but not controls. Body condition scores, cresty neck scores, and pasture analysis also changed with season, providing insight into ID-contributing factors. Authors’ addresses: Gluck Equine Research Center, Department of Veterinary Science, University of Kentucky, Lexington, KY 40546 (Macon, Barker, Miller, Adams); Equine Studies Group, Waltham Centre for Pet Nutrition, Melton, Mowbray, Leicestershire, United Kingdom LE14 4RT (Harris); Program for Neurology Research and Discovery, University of Michigan, Ann Arbor, MI 48109 (Elzinga); Department of Science and Health, Asbury University, Wilmore, KY 40390 (Siard); e-mail: Erica.Macon@uky.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction

Due to the prevalence of endocrinopathic-associated laminitis, especially at certain times of the year, it is important to examine seasonal factors contributing to insulin dysregulation (ID) and its determination via the oral sugar test (OST).

2. Materials and Methods

The OST was performed in the spring, summer, winter, and fall, on ID (n = 11; 14.2 ± 3.7 years) and noninsulin-dysregulated (NID) controls (n = 11; 16.4 ± 5.3 years) kept at grass with additional hay as required. Seasonal pre-OST blood samples (T0) and post-OST blood samples (T60), as well as body weight (BW), body condition scores (BCSs), and cresty neck scores (CNSs), were determined and samples of forages analyzed. Serum insulin was measured by radioimmunoassay at Cornell University. Data were analyzed using analysis of variance with repeated measures.

3. Results and Discussion

BW did not change across season in either ID or NID. However, BCSs and CNSs were higher (P < .05) in winter for both NID and ID compared with spring and fall. As expected, T0 and T60 responses differed (P < .001) between ID and NID; however, season did not affect these responses for NID horses (P > .275). Season did affect T0 and T60 responses of ID, with highest responses in winter and spring (P < .013). Crude protein and nonstructural carbohydrates varied across season in pasture (P < .001); however, no variation was found in hay (P > .116).

Acknowledgments

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Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA and the University of Kentucky IACUC.

Conflict of Interest
The Authors have no conflicts of interest.
How to Collect Cerebrospinal Fluid from Horses in the Field

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1. Introduction

Cerebrospinal fluid (CSF) is not routinely collected in the field owing to safety concerns and the need for time-sensitive sample handling. CSF is critical, however, for diagnosis of many equine neurologic diseases. Importantly, equine protozoal myeloencephalitis (EPM) is most accurately diagnosed with a CSF:serum ratio. While many practitioners treat EPM based on clinical signs and make the diagnosis on the basis of response to therapy, this is not a practical approach owing to the prolonged and expensive treatment protocol.

The lumbosacral (LS) centesis is the most widely accepted method for obtaining CSF from standing, sedate, adult horses. However, the horse’s reaction to this procedure can vary and poses a risk of injury to all parties involved. In the past decade, a technique for collecting CSF from a lateral position between the first and second cervical vertebrae (atlanto-axial space) was described in standing, sedate, adult horses. Since the time of original publication in 2012, this procedure has been gaining attention in part due to the appealing alternative of standing at the front end of the horse rather than the back end. A clinical study approved by the author’s Institutional Animal Care and Use Committee and the University’s Clinical Research Committee enabled direct comparison of the two techniques in terms of technical difficulty, horse reaction, and spinal fluid sample characteristics.

An additional reason CSF collection is not routinely attempted in the field is that the fluid does not have an extended shelf life when it comes to cytologic analysis. The samples must be processed rapidly as nucleated cells are prone to degradation in the low-protein environment of the CSF. A plan for processing the CSF must be determined before attempting to obtain a sample. The easiest way to ensure proper handling is to refer the case to a specialty hospital that has a clinical pathology laboratory on site. Recognizing this is not always feasible, alternative methods for appropriate sample handling are reviewed.

2. Materials and Methods

Part 1: CSF Acquisition

The location of the C1–C2 and LS CSF collection are demonstrated in Fig. 1. Adequate restraint and sedation are critical in standing, sedate, adult horses. Since the time of original publication in 2012, this procedure has been gaining attention in part due to the appealing alternative of standing at the front end of the horse rather than the back end. A clinical study approved by the author’s Institutional Animal Care and Use Committee and the University’s Clinical Research Committee enabled direct comparison of the two techniques in terms of technical difficulty, horse reaction, and spinal fluid sample characteristics.

An additional reason CSF collection is not routinely attempted in the field is that the fluid does not have an extended shelf life when it comes to cytologic analysis. The samples must be processed rapidly as nucleated cells are prone to degradation in the low-protein environment of the CSF. A plan for processing the CSF must be determined before attempting to obtain a sample. The easiest way to ensure proper handling is to refer the case to a specialty hospital that has a clinical pathology laboratory on site. Recognizing this is not always feasible, alternative methods for appropriate sample handling are reviewed.

2. Materials and Methods

Part 1: CSF Acquisition

The location of the C1–C2 and LS CSF collection are demonstrated in Fig. 1. Adequate restraint and sedation are critical for both procedures. Stocks, or an adequate barrier is recommended for personal safety when attempting the LS tap. The C1–C2 tap can be performed in stocks, in a stall, or in a quiet aisle way. The main limitation here is having access to the ultrasound machine. A nose twitch is recom-
mended for most horses when performing the LS tap. However, when performing the C1–C2 tap the author has found that some horses respond poorly to a nose twitch. In those cases, sedation and a trusted horse handler provided superior horse compliance compared with the addition of a nose twitch.

Sedation for both procedures must be chosen carefully and may have to be altered depending on the inherent nature of the horse and severity of the neurologic signs. An alpha-2 agonist, either romifidine (80 ug/kg; 40 mg/500 kg horse at least 10 minutes prior to procedure) or detomidine (0.01–0.015 mg/kg; 5–8 mg/500 kg horse 5 minutes prior to procedure) are administered intravenously. However, some horses with severe neurologic deficits can be adequately sedated with lower doses of either agent or with xylazine (0.3–0.6 mg/kg; 150–300 mg/500 kg). The author has noted that horses sedated with romifidine don’t drop their head as low, stand better, and are less ataxic following the procedure than with either detomidine or xylazine.\(^3\) In light of the current Drug Enforcement Administration (DEA) restriction on opioid manufacturing, both of these techniques were performed without the addition of opioid analgesia. Morphine was recommended and utilized in previous studies to provide dural analgesia. Butorphanol is purposefully avoided for the C1–C2 procedure since head twitching is a common side effect of butorphanol administration. In the author’s experience, there has been no observed response to needle puncture of the dura during the C1–C2 procedure. A few horses react modestly (head toss) to advancing through the cervical musculature if inadequate local anesthetic is used. In those situations, additional local anesthetic (2% lidocaine) is infused prior to proceeding. Occasionally, and unpredictably, horses react modestly (swished tails) to explosively (buck, kick out) in response to the LS centesis. This is not surprising as it is reported in the literature, and is the main cause for both horse and personal safety concerns related to LS taps.\(^4\) Based on having done many LS taps with and without the addition of butorphanol to an alpha-2 agonist, this reaction occurs irrespective of butorphanol administration.

C1–C2 Procedure

Horses should be clipped wide enough to include the footprint of the ultrasound transducer and the entire clipped site must be aseptically prepared (chlorhexidine scrub and 70% isopropyl alcohol). The mane should be braided or taped back to maintain a sterile field. Sedation with an alpha-2 agonist (romifidine or detomidine) can be administered before or after clipping and site preparation depending on how the horse tolerates preparation. The C1–C2 space is imaged laterally from either the right- or left-hand side of the horse with a 3.5-MHz convex curvilinear transducer (abdominal probe) set at a depth between 8 to 13 cm in a dorsoventral orientation. The subcutaneous tissue and cervical musculature are infiltrated with 5 mL of 2% lidocaine using a 1.5-inch 22-gauge needle in the optimal site for needle puncture. This site is immediately ventral to the transducer where it provides a clear image of the C1–C2 space and spinal cord. A final aseptic preparation is performed at the site prior to needle puncture. The transducer is kept sterile with a sterile glove to guide needle placement. The 3.5-inch 18-gauge needle is advanced in a ventrodorsal direction under ultrasound guidance with the target of the dorsal aspect of the subarachnoid space. In some horses, a distinct change in resistance (pop) is encountered upon puncturing the dura. When the needle is observed in the subarachnoid space, or a change in resistance is felt, the stylet is removed and a sterile, gloved finger is placed over the hub to prevent air from entering the space. After breaking the seal on the syringe, a 5-mL Luer Slip syringe is gently yet firmly hooked up to the hub and 1 to 2 mL of fluid is gently aspirated. This is generally repeated until enough fluid has been collected for diagnostic testing. A volume of 5 mL is generally an ample vol-
ume for cytology (generally 0.5 mL minimum required), bacterial culture if indicated, Sarcocystis neurona and Neospora hughesi antibody detection, and additional diagnostics as indicated by the history and clinical signs.

C1–C2 Spinal Fluid Collection

Fluid from the C1–C2 space occasionally drips spontaneously from the needle. In two cases, negative pressure was encountered once in the subarachnoid space precluding gentle aspiration. In these cases the CSF dripped freely with the head below withers height and with patience, allowed enough volume to be collected for cytology and minimal additional testing (~1.5 mL). Gentle aspiration is typically required to obtain the majority of the samples and routinely yields 5 mL or more with ease. Fluid is aspirated in 1 to 2 mL sequential aliquots as previously described to reduce the amount of blood contamination associated with the first sample. It is ideal to use 3 to 5 mL Luer Slip syringes (avoid Luer Lock) and it is important to break the seal on the syringe prior to aspirating the sample to prevent exerting excessive pressure on the meninges. The stylet is replaced and the needle is withdrawn smoothly once an adequate sample volume is obtained.

C1–C2 collection: typical yield, 5–8 mL.

Troubleshooting C1–C2 Spinal Needle Placement

If multiple attempts at needle placement occur, the needle track creates an artifact that obscures a clear image of the C1–C2 space and spinal cord. If this occurs, attempt the procedure from the other side following identical site preparation. If blood is obtained, it is likely that a vertebral vessel was inadvertently punctured. In this case needle placement is likely too ventral. The procedure can be repeated with a new needle with care to ensure that the needle is placed in the dorsal C1–C2 space. If negative pressure is encountered subsequent to switching syringes (especially after easy aspiration of the previous 1 mL) the stylet is replaced and the needle is advanced an additional millimeter and should result in easy aspiration of the remaining sample. In this case, it is most likely that the original needle placement is just through the dura and becomes displaced from the subarachnoid space during the transition from one syringe to the next.

LS Spinal Fluid Collection

Gentle aspiration is almost always required. A 5-mL Luer Slip syringe with the seal broken is preferred to provide adequate pressure to promote CSF flow. Ensure a solid connection between the needle hub and syringe. Fluid flowed freely from one case. In some cases, the Queckenstedt’s maneuver (transiently raising the head and holding off both jugular veins) is instrumental in increasing intracranial pressure thus promoting CSF flow and enhancing collection volume. Fluid is aspirated in 1–2-mL aliquots as described above. Typical yield, 5 mL.

Troubleshooting LS Spinal Needle Placement

If bone is encountered when the needle is at a depth of 3 to 4 inches, the needle is likely not in the proper location. Redirecting the needle is often unsuccessful. Reassessing the location of midline and selecting a slightly different location is usually required. It is also important to ensure the needle remains
perpendicular to the space as it is advanced. If bone is encountered at a depth of 5 to 7 inches the needle is probably in the LS space but has passed through the conus medullaris and contacted the floor of the spinal canal (Fig. 2). It is recommended to back the needle out in millimeter increments and check for fluid (replacing the stylet in between movements). In some cases spinal fluid can’t be obtained from the LS space. Reasons for this include anatomic variation, severe calcification of the ligamentum flavum, or obliteratorive spinal cord disease. Even with proper needle placement fluid might not be obtained in all cases due to a disruption in CSF flow due to a proximal lesion or an infiltrative lesion (mass effect). If blood is obtained, the needle placement is likely slightly off of midline. A clean spinal fluid sample can often still be obtained, but it is recommended to use a clean needle to reduce blood contamination.

Part II: Sample Handling and Submission
Now you have samples, what do you do? In general, CSF should be collected into sterile plain tubes (glass or plastic). Collecting CSF into ethylenediaminetetraacetic acid (EDTA) can falsely increase the protein concentration. It is important to note the quality of the CSF and gross fluid characteristics. Was there blood contamination? Was the fluid crystal clear? Or was the fluid cloudy or yellow (Fig. 3)? This is important to document as it can aid in diagnostic interpretation and provides useful clinical information. CSF should always undergo cytologic analysis. This is not only an essential diagnostic test for ruling out meningitis, but it aids in the interpretation of other tests. Careful and rapid sample handling is vital. CSF for cytology should be kept close to body temperature (avoid extreme temperature changes) and must be processed within 2 hours of sample collection. The nucleated cells in spinal fluid are unstable due to the low protein concentration and tonicity, which does not preserve cells well. Both mononuclear cells and neutrophils are reported to undergo degradation as the sample ages at either both room temperature or 4°C. If the sample will not make it to a lab for cytologic analysis within 2 hours, a cell-free albumin solution (such as autologous serum; 11% by volume; e.g., 0.11 mL per 1 mL) or a preservative such as 50% ethanol (use distilled water to make the appropriate concentration) at an equal volume to the sample volume can be added to one of the samples for cytology. This should only be done to the sample being submitted for cytology. The best sample for cytology is typically one of the last aliquots drawn. This reduces the effect of even microscopic blood contamination on the sample. If CSF is required for EPM antibody detection or other antibody detection, the samples with the least blood contamination (last sample) should be submitted. Samples for S. neurona or N. hughesi antibody detection should be kept refrigerated or can be frozen at −80°C if they aren’t able to be shipped within 48 hours (personal communication, Dr. Jennifer Morrow). Samples for culture should be placed into the appropriate culture media (blood culture bottle, bacterial or viral culturette). CSF for PCR should be collected in EDTA tubes. Remember to collect other clinically indicated samples such as serum for antibody detec-
tion, whole blood in EDTA for a complete blood count and fibrinogen concentration, whole blood in EDTA for equine herpesvirus-1 (EHV-1) PCR, serum or heparinized whole blood for a full biochemical profile, and nasal swabs when EHV-1 is a differential.

3. Results

Twenty-four horses, 16 healthy and eight neurologic horses had CSF collected from both the C1–C2 site and the LS site in immediate succession based on a computer-generated randomized order. In addition, nine horses underwent CSF collection at 2-week intervals. This resulted in a total of 42 procedures each of the C1–C2 and LS centeses. All horses were sedated with an alpha-2 adrenergic agonist as the sole sedative. Fluid was collected from both sites in all cases although total sample volume at an individual site varied between 1.5 and 6 mL. The time from needle puncture to spinal fluid collection was recorded for each site as well as the horse’s reaction. The average collection time for the C1–C2 tap was 6 minutes, whereas the average time for the LS tap was 8 minutes. However, 42% of C1–C2 taps were performed in under 3 minutes whereas only 20% of LS taps were completed in under 3 minutes. The horse reaction for the C1–C2 tap was minimal with only 2 horses making minor movements (head toss) during the needle advancement but prior to needle placement in the subarachnoid space. Reactions occurred more frequently with the LS tap, where 10 horses reacted by bucking, lunging forward, or kicking out with one leg. No horse jumped out of the stocks or fell down during the procedure. The author has, however, performed or witnessed over 120 LS taps and has witnessed on rare occasion horses fall in the stocks, jump forward out of the stocks, and put legs through the sides of the stocks.

Gross blood contamination occurs occasionally with both procedures. In one normal horse that underwent a C1–C2 centesis on two separate instances 2 weeks apart, the initial CSF was clear; however, minute streams of blood were detected flowing from the needle without any change in needle position or aspiration technique (presumptively from the meningeal capillaries). The third and fourth CSF aliquots were submitted for cytology and titer analysis to reduce the effect of blood contamination on analysis. Of the 84 total centeses, 28 were performed in the field. These samples were processed toward the end of the 2-hour cutoff and provided quality samples with no evidence of cellular degradation such as pyknotic nuclei, lysis, or disintegration of nuclear or cytoplasmic membranes. These samples were kept at ambient temperature (between 40°F and 60°F).

4. Discussion

CSF collection is an invasive procedure and should not be pursued without appropriate precautions and informed client consent. Irrespective of the approach, owners should be made aware of the main risks associated with CSF collection, which include introduction of infection, iatrogenic hemorrhage resulting in sterile meningitis, iatrogenic spinal cord trauma, or pain or swelling at the site.

The complication rate associated with CSF collection has not been reported. The author examined the horses in the study at 12-hour intervals for 48 hours following the procedure with no evidence of progression or development of neurologic signs, no evidence of cervical discomfort, or systemic inflammation based on physical examination. Some horses reacted to deep palpation of the C1–C2 site but this resolved at or prior to 48 hours without intervention.

Practitioners that are skilled at placing needles under ultrasound guidance will find the C1–C2 centesis less intimidating than those less confident with their ultrasound-guided skills. It is recommended that practitioners practice the technique on euthanized horses prior to attempting this procedure in a clinical case. In theory the needle could puncture the spinal cord. The risk of this is minimized by using no longer than a 3.5-inch needle, careful ultrasound guidance of needle placement, and positioning the needle in the dorsal subarachnoid space. In the five (seven) cases that had a post-mortem examination performed, no gross or histopathologic evidence of needle puncture was detected. When deciding which site to attempt to collect fluid from the pros and cons of both sites should be weighed. The main disadvantages of the LS tap include that they require stocks (or other physical barrier) to separate the person performing the tap from the horse. In addition, the handler must be prepared for the horse to jump or rush forward. The landmarks are sometimes difficult to discern in well-muscled or overconditioned individuals. Finally, as discussed previously, it is sometimes not possible to obtain fluid from the LS space. In those cases, it would be reasonable to attempt the C1–C2 tap on the same day. In the study performed by the author, there was no effect of order of the tap on the cytologic analysis. The benefit of performing the tap at the level of the LS space include being at a caudal location to a lesion localized caudal to C2. In addition, at the level of the LS space, the spinal cord is at or caudal to the conus medullaris as it terminates in the cauda equina (a collection of white matter tracts spinal nerves). Needle puncture of this segment is unlikely to result in neurologic deficits compared with accidental puncture of the spinal cord between C1–C2.

The benefits of the C1–C2 tap include being positioned to the side and at the front end of the horse. Little to no horse reaction was experienced with the use of appropriate local anesthetic, sedation, and restraint. In addition, this may be a more optimal site for neurologic lesions localized intracranially. The disadvantage is that it requires ultrasound equipment, moderate eye-hand coordination, and has the potential to traumatize the spinal cord.
The author has observed that the course the needle takes through the cervical musculature typically results in inserting the majority of the 3.5-inch 18-gauge needle before encountering the dura mater and made it appear unlikely that the needle would penetrate the spinal cord.

With experience and normal anatomy, the total time from needle puncture to CSF collection with either technique is under 5 minutes and often right around 2 minutes. The C1–C2 procedure offers a viable alternative to LS centesis if the practitioner does not have access to stocks and avoids the risks associated with atlanto-occipital centesis (mainly related to general anesthesia). Finally, collection of CSF in the field allows practitioners to rule out other neurologic diseases and make a more accurate diagnosis of EPM.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Effect of Valacyclovir on EHV-5 Viral Kinetics in Horses Diagnosed with Equine Multinodular Pulmonary Fibrosis

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This study revealed that 10 days of oral valacyclovir did not significantly alter equine herpesvirus-5 viral load in horses with equine multinodular pulmonary fibrosis and may not be an effective short-term antiviral treatment. Authors’ addresses: Veterinary Medical Teaching Hospital (Easton-Jones); Department of Medicine and Epidemiology (Madigan, Barnum, Pusterla), University of California, Davis, CA 95616; Department of Physiological Sciences, Center for Veterinary Health Sciences, Oklahoma State University, Stillwater, OK 74078 (Maxwell); Department of Veterinary Clinical Sciences, Purdue University, West Lafayette, IN 47907 (Taylor); Stillwater Equine Veterinary Clinic, Stillwater, MN 55082 (Arnesen); e-mail: caeastonjones@ucdavis.edu. *Corresponding and presenting author. © 2018 AAEP.

1. Introduction
Equine herpesvirus-5 (EHF-5) is commonly isolated from the lungs of horses with equine multinodular pulmonary fibrosis (EMPF), suggesting an etiological link. Valacyclovir is used empirically to treat EMPF; however, no data is available concerning its impact on EHV-5 viral kinetics. The objective of the study was to determine the effect of oral valacyclovir on EHV-5 viral load measured by qPCR in blood, nasal secretions, and bronchoalveolar lavage fluid (BALF) in six horses diagnosed with EMPF.

2. Materials and Methods
A prospective clinical trial was performed. Six horses received 10 days of oral valacyclovir. Blood, nasal secretions, and BALF were collected for EHV-5 viral kinetics analyses during treatment. Blood and nasal secretions were collected every other day. BALF was collected on day 0 and day 10.

3. Results
There was no statistical difference in median EHV-5 viral load in blood, nasal secretions, and BALF between day 0 and day 10.

4. Discussion
EHV-5 is a slow-growing gammaherpesvirus that is challenging to culture. As a result, the IC50 for EHV-5 is currently unknown. The dose or length of treatment of valacyclovir in this study may, there-
fore, have been inadequate to alter EHV-5 viral loads. Horses with EMPF had a poor outcome in this study. Differences in survival times noted in this study and previous studies may be indicative of varying phenotypes with different rates of progression.

Acknowledgments
The use of valacyclovir in horses in this study was off-label.
Sample collection and animal use was approved by the Institutional Animal Care and Use Committee at the University of California at Davis. Owner consent was obtained for animals used in this study.
This Project was funded by the Center for Equine Health, University of California, Davis.

Declaration of Ethics
The Authors have adhered to the Principles of Veterinary Medical Ethics of the AVMA.

Conflict of Interest
The Authors have no conflicts of interest.
Case-Based Approach to Common Business Challenges: Fraud, Theft, and Embezzlement

Tera L. Nance

1. Introduction
In a 2011 survey of 183 Veterinary Study Group member practices, nearly 68% reported being a victim of fraud, theft, or embezzlement by an employee. According to the 2014 Report on Occupational Fraud, the median loss for employee fraud is $145,000 and the average owner fraud is $500,000. Be Prepared!

2. True Story and “What Would You Do” Discussion
This paper will walk through an unfortunate true story of a client of the author’s who experienced embezzlement. The names and some details have been changed to protect the innocent. The practice was experiencing high profits, but didn’t have the cash to pay their bills. When the practice owner started looking more closely at the books, he noticed the daily deposits didn’t match the client payment reports from their practice management software. After spot checking several, he noticed that on days the office manager was on vacation, they tied to the penny. The office manager was a family friend and long-time employee. The practice owner called an expert to take a look. Embezzlement was immediately verified. Well over $250,000 within 2-year span was discovered. This paper will go through each of the steps that were taken afterward in this situation along with the measures to prevent it from happening again. Each step you should put yourself in the practice owner’s shoes and ask yourself, if it were you, what would you do?

3. Embezzlement and Fraud Statistics
Ever heard of the 10-10-80 rule? Ten percent of people will never steal no matter what, 10% of people will steal at any opportunity, and the other 80% of employees will go either way depending on how they rationalize a particular opportunity. According to the Association of Certified Fraud Examiners (ACFE), employee fraud goes on for an average of 18 months before detection. In 81% of fraud cases, the guilty party displayed at least one of the following signs: living beyond their means, close relationships with vendors or customers, financial problems, and excessive control issues. Digging further into our industry as a whole, according to statistics, approximately 33% of veterinary offices have been or will become the victim of employee embezzlement this year.

4. Definitions and Levels of Fraud
Theft—taking something from another person without the consent of that person. Someone breaking into your car and stealing your purse or stereo, for example. Fraud—intentional deceit over another to gain profit and an untruthful advantage, taking
money or other valuable things from other people. Email scams or gimmicks on social media are good examples. **Embezzlement**—involves an employee or a representative that funnels money or property owned and paid to the employer to his or her own personal account for his/her own personal use without the consent or knowledge of the victim-employer. An employee putting cash received by clients into their pockets or an employee using a company credit card for personal purchases are some instances. An employee cheating on a time card is also another form of embezzlement. The main difference is that in embezzlement, the employee is usually entrusted with the property or reasonability by the employer.

5. Characteristics of Employees Who Steal and Their Motives

According to an ACFE report, 54% of fraudsters are between the ages of 31 and 45 years, are females in management or accounting positions, and are long-term, trusted employees. Other fraudulent employee behaviors include excessive spending, living beyond their means, and unusually close relationships with vendors or customers, excessive control issues, and refusal to take vacations. Employees who were deemed disgruntled or had bad attitudes of entitlement are frequent embezzlers.

6. Early Warning Signs

Some signs to pay attention to in your practice include if your practice is profitable, but has unexplained low cash flow, similar to our true story example. You will have a good idea of how much is normally put on your practice credit cards. If you notice they are unusually high 1 or 2 months, check it out. Many times inventory discrepancies can uncover theft. Any bank reconciliation differences must be addressed immediately. You should be in the habit of seriously looking through bills and invoices taking note of any strange ones or anything out of the ordinary. If there is zero or vague reporting or transparency from the person in charge of the money or books, that is a warning sign as well. Any data inconsistencies or absence in the archives could be one too. Pay attention to gossip. Gossip in overdrive usually means where there is smoke, there is fire!

7. Ways to Prevent Embezzlement

Internal controls! Internal controls! Internal controls! It can’t be said enough. Separation of duties is vital in a practice. Have different office staff receive payments, post payments, and make deposits. Have a different person ordering drugs than the person receiving in and counting. Separate the person/department that is processing or writing the checks from the person/department that reconciles the bank statements. Limit check signing duties to only the practice owners! Limit access and issuance of company credit cards as much as possible. Have all reconciliations of accounts receivable, credit cards, and banks done by an employee with no access to those transactions—do it yourself as the owner, or pay your CPA or accounting professional to do it. Review all payroll before it is processed. In smaller practices with fewer employees, it’s difficult to completely segregate duties, so the owner will then have to stay more closely involved. The more awareness/involvement in the accounting transactions and finances done by the owners, the less likely anyone will be tempted or have the opportunity to steal.

8. What to Do if You Suspect Fraud

If you suspect fraud, be discrete about your suspicion. If you let on to the person that you suspect it and don’t have time to prove it or do anything else about it, you give them ample time and opportunity to cover it up. Consult an accounting/fraud expert to get proof, preferably an expert with knowledge of your industry and software. Hard proof is needed before accusing someone of something so serious. Consult an employment attorney on your options once you have proof. Formulate plans based on all your options and or potential outcomes of employee responses once confronted. Confront the employee with the proof in the presence of an independent eyewitness, or two, or three. Either way, if the employee denies or confesses and you have solid proof, immediately relieve them of their job responsibilities and company possessions and personally escort them from facilities or have a police officer do it if you think things could get ugly. Start the legal process of prosecution and or repayment plan immediately. In cases such as these, any time lapse can weaken your case. Check your insurance policy for coverage. A lot of business policies will cover employee embezzlement.

Far too often practice owners say, “not on my watch,” “it can’t happen here,” or “we are like family,” and far too often those same owners saw red flags or warning signs from employees and chose to ignore them because of those misconceptions. The intention is not to scare anyone or create unnecessary fear. It’s not paranoia, its prudence. As Ronald Reagan said, “Trust, but verify.”

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Ambulatory Vehicle Ownership: Employer or Employee?

Jorge L. Colón, DVM, MBA

Expenses for the business use of vehicles in an ambulatory practice will create a significant cash outflow for the practice and for the entity owning the vehicle (employer or employee). Because who owns the vehicle and which method is used to account for expenses will affect the total cash outflow, vehicle ownership, and accounting method should be business decisions based on proper analysis of the cash expenses expected to be incurred during the life of the vehicle. Author’s address: Jorge Luis Colón, DVM, PLLC, PO Box 11631, Lexington, KY 40576; e-mail: jorgecolondvm@me.com. © 2018 AAEP.

1. Introduction
Ambulatory vehicles are an essential asset of any ambulatory veterinary practice. Each vehicle will incur a significant amount of expenses throughout its useful life associated with purchase costs, registration fees, fuel, and maintenance, among others. The business can account for these costs in different ways depending on who owns the vehicle. Even if the employee owns the vehicle, the veterinary business will most likely incur vehicle expenses through employee reimbursement for business usage of a personal vehicle. Because cash will be consumed by the payment of these costs, whether through vehicle costs or mileage reimbursement expenses, these payments will create a cash outflow from the pocket of the employer and/or the employee. Understanding the expected cash outflows for an ambulatory vehicle should allow the business to make better decisions regarding ambulatory vehicle ownership.

2. Expensing a Vehicle
Internal Revenue Service (IRS) tax rules allow vehicle expenses to be accounted for through a standard mileage rate ($0.545 per mile for 2018) or through actual expenses incurred based on detailed records. The method that one can use, however, depends on who owns the vehicle (employee or employer) and on the employer’s business organization status.

If the veterinary practice is a corporation or an S-corporation and the business owns the vehicle, vehicle expenses can only be accounted for through the actual expenses method. The actual expenses method allows the corporation or S-corporation veterinary practice to deduct all of the expenses incurred during the business use of the vehicle, including the depreciation of the asset.

If the veterinary practice is a limited liability company (LLC) or a partnership and the business owns the vehicle, the business can choose to account for vehicle expenses using either method, but it would have to meet certain requirements in order to use the standard deduction (mainly, not having claimed a section 179 deduction on the vehicle, not having used any depreciation method on the vehicle other than straight-line, and not having five or more vehicles being used simultaneously). The standard mileage rate allows the deduction of the amount...
generated by the mileage and rate calculation but eliminates the ability to deduct actual expenses, including the deduction for depreciation.

If the vehicle is owned by an employee (which could be a practice associate under any business organization or the business owner of an LLC, partnership, or S-corporation acting as the employee), the employee can calculate their “business use of vehicle” expenses through the standard or actual expense method and account for the expenses through their itemized deductions on their personal taxes. Most veterinary practices that rely on employee-owned vehicles, however, choose to pay the veterinary employee the standard mileage rate (or a percentage of it) to compensate for the business use of the personal vehicle. The amount paid to the employee is accounted for as a vehicle expense for the business and becomes nontaxable income for the employee; in this case, the employee would not have a deduction on their personal taxes for vehicle expenses.

3. General Vehicle Information

The author performed an informal survey of veterinary colleagues and members of the AAEP Business Rounds discussion group by asking four basic questions regarding their ambulatory vehicle: (1) average miles driven per year, (2) average miles per gallon (mpg), (3) service cost expenses per mile, and (4) make and model of vehicle. Responses from about 65 people, together with some vehicle price and taxes/licenses/fees, research allowed the author to make a few major observations:

1. Almost all of the ambulatory vehicles fit into one of three categories based on vehicle type: (a) pickup trucks, (b) large sport utility vehicles (large SUVs), and (c) medium sized sport utility vehicles, minivans, and hatchbacks (medium SUVs).
2. The average miles per gallon and service cost per mile reported and the researched average vehicle price point were distinct between each of the three vehicle categories.
3. All vehicles, regardless of price point, would carry an additional “license, registration, and fees” cost at the time of purchase. Based on the author’s state and county of residence (Lexington-Fayette County, KY), this additional cost added, on average, 10.20% to the purchase price.
4. The average of all reported miles driven was 34,000 miles per year, although the responses were wide ranging, with a low of 12,000 and a high of 90,000.
5. American Automobile Association (AAA) data from 2017 suggest that the average yearly price for personal vehicle insurance and for license/registration/taxes is $1,178 and $718, respectively. The national average price of regular gasoline on the date of this writing was $2.52.

4. Vehicle Categories

Medium SUVs

These vehicles were represented by medium-sized SUV models and hatchbacks from all major manufacturers (i.e., Toyota 4Runner, Ford Explorer, Kia Sorento, Honda Pilot, Chevy Traverse, Subaru Outback, and others). Medium-sized SUV users reported an average of 20.14 mpg and an average of $0.0589 service costs per mile. The researched average price point was around $34,000 (See Table 1).

Large SUVs

These vehicles were represented by large-sized SUV models from all major manufacturers (i.e., Toyota Sequoia, Ford Expedition, Chevy Suburban, Chevy Tahoe, GMC Yukon, Cadillac Escalade, and others). Large-sized SUV users reported an average of 16.06 mpg and an average of $0.0610 service costs per mile. The researched average price point was around $55,000 (See Table 1).

Pickup Trucks

These vehicles were represented by models from all major manufacturers (i.e., Toyota Tundra and Tacoma, Ford F150 and 250 Series, Chevy Silverado, Ram 2500, GMC Sierra, and others). Pickup truck users reported an average of 15.11 mpg and an average of $0.0675 service costs per mile. The researched average price point was around $37,000 (See Table 1).

5. Vehicle Expenses

To estimate the cash outflows associated with the vehicles, the author made three assumptions: (1) that veterinarians would be organized under pass-through income organizations (i.e., S-corporations, LLCs, or partnerships) and that their marginal personal tax rate would be 24%, (2) that the employer’s ultimate cash outflow as an individual would be based on the business cash outflows as the business owner, plus the tax reductions at the individual level based on the reduced pass-through income created by the business vehicle expenses (i.e., if the business incurred $100 of vehicle expenses, the individual’s pass through net income would be reduced by $100 and would therefore pay $24 less in personal taxes,

Table 1. Ambulatory Vehicle Categories Based on Vehicle Type and Their Corresponding Averages Based on Survey Data, Price Research, and $2.52 Average National Gas Price

<table>
<thead>
<tr>
<th>Category</th>
<th>Cost</th>
<th>mpg</th>
<th>Service Cost/mile</th>
<th>Fuel Cost/mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium SUV</td>
<td>$34,000</td>
<td>20.14</td>
<td>$0.0589</td>
<td>$0.1251</td>
</tr>
<tr>
<td>Large SUV</td>
<td>$55,000</td>
<td>16.06</td>
<td>$0.0610</td>
<td>$0.1569</td>
</tr>
<tr>
<td>Pickup truck</td>
<td>$37,000</td>
<td>15.11</td>
<td>$0.0675</td>
<td>$0.1668</td>
</tr>
</tbody>
</table>
thereby making the employer’s total cash outflow $76), and (3) that, for a business to use the standard rate, it must depreciate the vehicle in a straight-line method and the depreciation timeframe for a business vehicle is 5 years, the expense calculations would be made for a 5-year period.

Vehicle-related cash outflows include costs for purchase and financing, for taxes, registration, and licenses (at purchase and yearly), and for fuel, service, and insurance. Table 2 presents an example of the expected cash expenses for a large SUV driven 34,000 miles annually under the parameters described beforehand.

An employer-owned vehicle using the actual expenses method would get to add the noncash depreciation expense to the actual cash expenses in order to reduce net income and therefore reduce the taxable income at the individual level. Note that the example depreciates 100% of the vehicle; in reality, an asset should never be depreciated below the expected salvage value (or the vehicle’s potential trade-in value). Table 3 presents the employer’s total cash outflow as an individual after taking into account the tax savings created by the reduced pass-through income because of the depreciation expense.

An employer-owned vehicle using the standard rate method will have a reduction in taxable income as an individual based on the standard rate expenses sustained by the business; the combination of this tax savings with the actual cash expenses incurred will provide the employer’s total cash outflow as an individual. Table 4 presents this cash outflow scenario for the same large SUV vehicle described above.

An employee with a vehicle who is reimbursed by the employer using the standard rate method will create a scenario with two cash outflow components: the cash outflow for the employer (standard rate payments and tax savings as individual) and the cash flow for the employee (standard rate income minus actual cash expenses). If the employer is also the employee, the net cash flow from employer plus employee will be identical to that described above for an employer-owned vehicle by using the standard rate. If the employee is not the employer, however, both cash flow components must be analyzed separately to see the expected cash flows for each entity. Table 5 presents the two cash flow portions related to employee ownership of the same large SUV vehicle in the example.

6. Additional Insurance Expenses

The average insurance cost used for the example and calculations, which was obtained from the AAA reference, is related to personal vehicle costs and therefore may underestimate the true cost of business-use vehicle insurance. If the business owns the vehicle, the insurance for the vehicle will undoubtedly be provided by the insurance company as business-use insurance. It is the practice’s additional cost and responsibility to add all of the potential drivers of the practice’s vehicles to the insurance policy.

If the vehicle is employee owned, the owner must ask their insurance provider to cover the ambulatory vehicle under a business-use label within their personal policy. It is the individual owner’s additional cost and responsibility to add all of the potential drivers of that vehicle during the course of business operations to his/her own business-use personal policy. If the veterinarian does not have a business-use label on their personal policy for the employee-owned ambulatory vehicle, that veterinarian is practically driving uninsured during the course of business operations. And if the veterinarian’s technician is driving the vehicle and is not covered inside of the veterinarian’s business-use

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**Table 2. Expected Cash Expenses Over 5 Years for Large SUV Driven 34,000 Miles Annually**

<table>
<thead>
<tr>
<th>Expense Item</th>
<th>Annual Cost ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Car payment ($55K plus 10.2%; 0% financing)</td>
<td>(60,610)</td>
</tr>
<tr>
<td>Fuel cost ($0.1569115/mile)</td>
<td>(26,675)</td>
</tr>
<tr>
<td>Service cost ($0.0610/mile)</td>
<td>(10,370)</td>
</tr>
<tr>
<td>Insurance ($1,178/year)</td>
<td>(5,890)</td>
</tr>
<tr>
<td>License/registration/taxes ($718/year)</td>
<td>(3,590)</td>
</tr>
<tr>
<td>Total cash expenses</td>
<td>(107,135)</td>
</tr>
</tbody>
</table>

---

**Table 3. Expected Cash Outflow Over 5 Years Using the Actual Expense Method for Employer-Owned Large SUV Driven 34,000 Miles Annually**

<table>
<thead>
<tr>
<th>Expense Item</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual cash expenses incurred</td>
<td>(107,135)</td>
</tr>
<tr>
<td>Depreciation expense (noncash expense)</td>
<td>(60,610)</td>
</tr>
<tr>
<td>Tax savings as individual (24% marginal rate on cash + depreciation)</td>
<td>40,259</td>
</tr>
<tr>
<td>Total cash outflow (actual expenses plus tax savings)</td>
<td>(66,876)</td>
</tr>
</tbody>
</table>

---

**Table 4. Expected Cash Outflow Over 5 Years Using the Standard Rate Method for Employer-Owned Large SUV Driven 34,000 Miles Annually**

<table>
<thead>
<tr>
<th>Expense Item</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Actual cash expenses incurred</td>
<td>107,135</td>
</tr>
<tr>
<td>Standard rate expenses ($0.545/mile)</td>
<td>92,650</td>
</tr>
<tr>
<td>Tax savings as individual (24% marginal rate on standard rate expenses)</td>
<td>22,236</td>
</tr>
<tr>
<td>Total cash outflow (actual expenses plus tax savings)</td>
<td>84,899</td>
</tr>
</tbody>
</table>

---

**Table 5. Expected Cash Flows Over 5 Years for Employer and Employee Using an Employee-Owned Large SUV Driven 34,000 Miles Annually Being Reimbursed Using the Standard Rate Method**

<table>
<thead>
<tr>
<th>Expense Item</th>
<th>Amount ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard rate employer expenses ($0.545/mile)</td>
<td>92,650</td>
</tr>
<tr>
<td>Tax savings as individual (24% marginal rate)</td>
<td>22,236</td>
</tr>
<tr>
<td>Total employer cash outflow</td>
<td>70,414</td>
</tr>
<tr>
<td>Tax-free employee cash inflow ($0.545/mile)</td>
<td>92,650</td>
</tr>
<tr>
<td>Employee vehicle expenses cash outflow</td>
<td>107,135</td>
</tr>
<tr>
<td>Total employee cash flow</td>
<td>14,485</td>
</tr>
<tr>
<td>Employer + employee cash flow</td>
<td>84,899</td>
</tr>
</tbody>
</table>
personal policy, any accident incurred while that person is behind the wheel would not be covered either.

7. Results

Table 6 presents the resulting 5-year total cash flows produced by the three different vehicle categories being driven for 25,000, 34,000, and 50,000 miles annually, based on the assumptions and variables previously described. Although it is understandable that the lower mileage vehicle should probably last more than 5 years and that the higher mileage vehicle may not necessarily make it to 5 years, the presented results give a fairly accurate idea of the difference in cash flows between the different ownership and accounting method combinations for the three vehicle categories.

The results suggest that an employer would have a lower total cash outflow under most scenarios presented if the employer owned the vehicle and used the actual expenses method. For the situation where the employer is looking at a vehicle as an employee, the only time it would be more beneficial to own the vehicle as the employee would be if the vehicle was a medium SUV being driven 50,000 miles annually. For the situation where the employer is looking at a vehicle for an employee (non-self), the only time it would be more advantageous for the employer to have the employee own the vehicle would be if the vehicle was a large SUV being driven 25,000 miles annually.

It is important to note that for the employee who is being reimbursed for the use of their own vehicle, the employee cash flows could actually be negative, as is the case within this example with a large SUV driven 34,000 miles annually and with all the vehicles driven 25,000 miles annually. This scenario is created when the total tax free vehicle reimbursement income is less than the total actual cash expenses over the presented 5-year period. On the other hand, this example shows lower-priced vehicles driven for greater miles annually (specifically medium SUVs and pickup trucks), creating an income stream for the employee that might provide sufficient funds to cover their future vehicle replacement. Table 7 presents the resulting cash expenses per mile for each vehicle category over the 5-year period depending on the number of miles driven annually, a number that can be compared with the current standard federal mileage rate of $0.545 per mile.

8. Important Nuisances to Employer Ownership

Potentially reducing total cash outflows through employer vehicle ownership comes with important caveats. It is very difficult to justify 100% of all the vehicle miles as business use; personal use of a business-owned vehicle will trigger complicated fringe benefits rules from the IRS onto the employee. Also, for employer ownership to be legitimate, the business name needs to be on the title at the time of purchase; transferring a personally purchased vehicle to your business can and will elicit a sales tax on a vehicle you already paid tax on. Lastly, vehicle insurance rates for businesses are usually higher than business-use rates under personal policies, plus the business will always be on the hook for any insurance claim even if the vehicle was under personal use at the time of the accident. The potential cash savings of employer-owned ambulatory vehicles must be weighed against the nuisances created by the ownership situation.

9. Conclusion

Although the variables that went into this exercise were numerous and some generalizations and assumptions are necessary, the results presented here should offer useful guidance to employers on the most advantageous ownership and accounting method combinations for their particular vehicle categories.
sumptions had to be made, the results suggest that most veterinary practices would benefit, cash-flow wise, from employer-owned ambulatory vehicles that are accounted for through the actual expense method. Medium SUVs would be the least cash-flow intensive ambulatory vehicles due to their lower purchase price, higher miles per gallon, and lower service cost per mile when compared with the other two vehicle categories. The large SUVs seem to be the most cash-flow intensive, mostly due to their higher purchase price combined with a much lower mpg than that of medium SUVs. Pickup trucks seem to fall between both SUVs because their lower mpg and higher service cost per mile gets balanced out by a lower purchase price that is closer to that of a medium SUV.

Changes in variables such as fuel price, service cost per mile, and length of vehicle life expectancy will undoubtedly change the obtained results and might present different advantageous situations for the practice or for the employee within the three vehicle categories. Variations in vehicle fees, insurance rates, and financing needs due to geographic and personal differences between veterinarians will also affect the results.

Purchasing used vehicles with low miles may provide an avenue toward lower cash outflows for all vehicle categories based on lower purchase price and lower starting point for insurance rates and for license/registration/tax calculations without a necessary increase in initial service cost per mile. For example, the self-employed author purchased a used medium SUV with 16,000 miles at a 35% discount from a new version of the same model. The lower personal expenses associated with lower cost, lower insurance rates on a used vehicle, and lower starting point for property taxes and license/registration fees have created a reduced cash outflow situation even though the vehicle is employee owned and driven only 25,000 miles annually.

Although the needs and requirements of a specific practice should dictate the type of ambulatory vehicle needed, understanding the expected cash flows created by these vehicles should allow practices to make better decisions to reduce unnecessary cash outflows, which ultimately reduce practice value.

Acknowledgments

Declarations of Ethics

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

Conflict of Interest

The Author has no conflicts of interest.

References

Cash Management for Equine Veterinary Practices: Cash is King

Tera L. Nance

Cash-flow management can be practiced to a point where every available dollar is at work either covering payment of checks or producing income. A practice has to generate an adequate cash flow from its operations in order to survive. In addition to generating cash from its activities, a practice also needs to manage its cash situation so that it holds the right amount of cash to meet its immediate and long-term needs. Managing your cash in a proactive way can reduce stress and ensure practice stability. Recognizing your cash flow and understanding where there is room for improvement is crucial for all practice owners, and these cash management techniques are the first steps to helping you become more cash-wise. Author’s address: 5125 South Kipling St., Suite 300, Littleton, CO 80127; e-mail: tera@summitveterinaryadvisors.com. © 2018 AAEP.

1. Relevance

Too often profitable veterinary practices fail. How, you say? Cash… or lack thereof, that’s how. They can generate plenty of profits, but what the practice owner chooses to do with those profits or the excess cash can make or break it. Having too little or sometimes too much money can create serious problems. Successful practice owners know how to manage cash. Cash is the lifeblood of a practice and a practice needs to generate enough cash from its operations so that it can meet its expenses and have enough left over to give something back to the practice owner all the while continuing to grow and invest in the practice. While a practice can fudge its earnings, its cash flow provides a true picture about its real health. It sounds trite, but it’s really true that cash is king.

2. What Exactly is Cash Management?

Cash flow management is a process that involves collecting payments, controlling disbursements, covering shortfalls, forecasting cash needs, and investing idle funds or growth for the practice. It is a key component of ensuring a practice’s financial stability and solvency. Even if a company is profitable, it will have to manage its cash flow appropriately to be successful. A practice’s cash flow is tied to its operations or business activities, to its investment activities (such as the purchase or the sale of digital radiographs (DRs), ultrasounds, and shockwaves), and to its financing activities (such as raising debt or equity funding or repaying such funding). The cash that a practice generates from its operations is tied to its core business activities and provides the best opportunities for cash-flow management.

3. Strategies for Optimizing Your Cash Management

Receiveable and Payable Management

If vendors are demanding payables in 30 days and clients are paying you in 45 days, you will run out of money. Areas that offer possibilities for better cash
management include accounts receivable, accounts payable, and inventories. If a practice were to grant credit indiscriminately, without determining the credit worthiness of its clients, and not follow up on past-due accounts, that would lead to a slower and smaller inflow of cash. That is why it is important to have a credit policy and follow up on past-due payments. Establishing an interest charge policy for late payments by customers may also help with timely collections. Offering your clients easy and quick ways to pay such as online payments or auto payments will definitely help increase your cash flow.

On the other hand, when it comes to accounts payable, it is better cash management to pay vendors later rather than earlier. It is also important not to have too much cash tied up in inventories, but to have on hand just enough drugs and medical supplies for the immediate needs of the practice. After all, you don’t want your dollars sitting on a shelf waiting to expire. Another way to maximize cash is to structure purchase agreements with vendors to include discounts for early payment. Cash management is not just a financial issue; it’s an operational issue as well.

The Right Balance
There is a genuine balance between having too much cash on hand, out of precaution, and having an inadequate supply. If a practice has too much cash, it is missing out on opportunities to invest that cash into something like a new rehabilitation department or investment in new lab equipment, thereby generating additional earnings. On the other hand, if it doesn’t have an adequate supply of cash, it will have to borrow the money, and pay interest, or sell off its liquid investments to generate the cash it needs, sometimes not just to grow the practice, but even to simply make the next payroll. It is good to get in the habit of setting aside small amounts to fund large expected expenditures such as Professional Liability Insurance Trust (PLIT) insurance, retirement contributions, or quarterly estimated tax payments. You may also want to start an equipment fund to save up for large capital assets that will eventually need to be replaced. Being prepared for large purchases with a fully funded savings account will give you peace of mind all year long. I highly recommend practices obtaining a reasonable line of credit with a bank. Short-term financing such as a line of credit can be used to make emergency purchases or to bridge the gap between payables and receivables. A line of credit can be negotiated with your financial institution. This should be done before any need actually arises. It’s usually easier to negotiate a line of credit when you don’t really need one. A good time to go to your banker is immediately after the end of a good year or quarter. A line of credit should be used responsibly and considered as short term and repaid back as soon as possible.

Metrics of Measuring Cash
Analyze cash every month. Analyzing cash doesn’t have to be complicated. Start by writing down your cash balance at the beginning of the month, and then add all the cash that came in during the month from all sources. Finally, subtract all of the outgoing cash and calculate the ending cash balance. After a few months, review the ending cash balances of each month and compare them. If your cash balance is decreasing month after month, then your business has a negative cash flow, which is not good. If the ending balance is increasing, then your cash flow is positive, which is the goal. You should keep record of the cash balances over the course of a year and run a trend analysis to determine the causes of the ups and downs. If you are funding your business with loans, be sure to leave this money out of the analysis so you can gauge the true cash flow from operations. Taking analytics even further, in analyzing a practice’s balance sheet, certain ratios such as a practice’s acid-test ratio, or the ratio of its most liquid current assets (including cash, accounts receivable, and inventories) to its current liabilities provide an idea about its cash management. While a ratio of greater than one indicates a healthy current asset situation, a very high ratio could indicate that the firm holds too much cash or other liquid assets. Operating Cash Flow/Net Sales ratio, which is expressed as a percentage of a company’s net operating cash flow to its net sales, or revenue (from the income statement), tells us how many dollars of cash we get for every dollar of sales. There is no exact percentage to look for but obviously, the higher the percentage the better. It should also be noted that industry and practice ratios will vary but can still be benchmarked. Owners or practice managers should track this indicator’s performance historically to detect significant variances from the practice’s average cash flow/sales relationship along with how the practice’s ratio compares to its peers. Also, keep an eye on how cash flow increases as production increases; it is important that they move at a similar rate over time. Keeping your practice’s books real time will allow you to measure cash on any occasion.

Develop Cash Forecasting
A good cash-flow analysis might be the most important single piece of a business plan. All the strategy, tactics, and ongoing business activities mean nothing if there isn’t enough money to pay the bills. And that’s what a cash flow projection is about—predicting your cash needs in advance. Because of the uncertainty of cash flows, practices can use forecasts to help offset these uncertainties and match incoming receipts with disbursements. Forecasts are based on seasonal, monthly, daily, and cyclical patterns as well as trends. Forecasts can be further divided into short term (covering 1 day to 2 weeks), medium term (covering a few weeks up to 1 year), and long term (covering 1 to several years).
Typically cash forecasts are done on a quarterly basis measuring cash about two weeks or a month out from when estimated taxes and distributions are due. Integrating information into the forecast as soon as it is obtained, using a “rolling” format so that updating is continuous, helps the practice time cash outlays to meet incoming deposits. Further, use of a rolling forecast improves forecasting accuracy and can see the practice through cash-critical periods.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.
1. Introduction

Deciding what matters to you and to your practice will be the greatest determining factor in whether or not you ever arrive at the predetermined destination. Put simply, failing to decide is the single best way to fail to achieve. This is the overriding theme when it comes to an associate buying into a practice. The earlier a practice owner makes his/her exit strategy a priority, begins making decisions about that strategy, and begins acting in accordance with the expectation of that outcome, the more likely they will achieve the desired result. Likewise, for an associate, the earlier one recognizes whether or not they are interested in practice ownership, the better they can position themselves to achieve that outcome.

For many practices, the concept of having an associate buy into the practice isn’t always an area of focus that is properly cultivated or timely addressed, and may only be given deep consideration at the point that the associate has become disgruntled, is perhaps considering leaving to join another practice, or has determined to strike out on their own. Having a plan for associate buy-ins requires specific decision making at several key stages during the employee’s tenure with the practice. The key is knowing when you are at the crossroads for each of those decision-making points, so that you can align your long-term goals for ownership transition with the available talent in your practice.

As an owner in a veterinary practice, the demands on your time can be immense and the focus of your efforts ranges widely. From dealing with an emergency colic, to calling a creditor to inquire about a bill, to addressing a staffing situation, your days are flooded with issues that require your focus on the immediate. Distractions become commonplace and dedicating meaningful time to the areas that matter most is challenging. This underscores the need for a multi-phase plan for cultivating the future owners of your practice.

The transition from associate to owner is much more than a simple financial transaction. It is a process that requires time, mentorship, trust, and empowerment. Understanding your long-term vision for practice ownership, communicating that vision to your associates, and fostering an environment that supports those goals, will put you and your associates in good stead as you move along the roadmap toward ownership transition.

2. The Roadmap

What matters to you as a practice owner? What is it that you value most about being the owner of your practice? Do you value control and the ability to
orchestrate the direction of your business? Year-end profitability? Owner distributions? Having control over your schedule, giving you time to pursue interests outside of veterinary medicine? It could be any of these, and likely includes a mixture of all of them. But as an owner, you have come to understand the realities of ownership. Regardless of how high your production is, or what level of expertise you attain, or even what level of status you enjoy among industry professionals, at the end of the day, you own a business, and that business requires you to function as a business professional. It requires planning, executing your strategy, and having a well-tuned financial reporting system. It requires daily attention to a multitude of areas to achieve any given outcome. Whether it is the decision to acquire a new piece of diagnostic equipment or to expand your services to include alternative therapies, each area of growth begins with the matter of where that outcome can take the practice in the future and what does it mean today? Similarly to any important aspect of your practice, a plan to properly convey your interest to the next generation of veterinarians demands no less attention. It requires thoughtful consideration well in advance so that you can make the daily adjustments to cultivate the future practice owners that will ultimately take your place. How would a plan like that actually look? How do you know if you’re on track? How do you keep score?

Keeping Score as a Practice Owner
At some stage of practice, maybe even all the stages of your practice lifecycle, your personal production as a veterinarian is a key indicator of your value as a veterinarian. It is how you define your worth to the practice, at least financially. If you are in a commission-based practice, your personal production is vital. It is the yardstick of determining how you get paid. You become accustomed to expecting monthly, quarterly, and year-end production reports, and as an owner, being privy to all levels of production in your practice, it is easy to compare your production to the rest of the team. It feels good to be a large producer. But production is only one way of keeping score.

At some stage, the way you keep score may need to change. Your personal production requires your personal physical effort. That realization leads to the question of how to maintain revenues at a certain level without having to physically be the one doing everything, given that your time and attention are needed in so many other facets of your business. Remember, if you physically have to be there to make the wheel go round, you are operating less like a business and more like an employee. When that realization sets in, you’ll begin to see yourself more as a business owner commanding an enterprise, and less as a physical provider of professional services.

Your impact can be made in a myriad of ways: by growing production, by driving caseload to the most profitable areas of the practice, by creating relationships with key clients. You may focus your efforts on starting new areas of service, or enhancing the level of service to your existing clientele. In sum, your ability to transition caseload and key clientele to new associates, building their confidence and mentoring their development along the way, will be a vital piece of a successful associate buy-in, provided that you have the right candidates in place. Consider your current method of scorekeeping in your practice, and whether or not you are actively cultivating that next generation of veterinarians.

Recruitment
The associates that you select, hire, and promote as your team will have a tremendous impact on your success as a practice. If you hire dynamic personalities with high-level veterinary skills, your chances for growing your clientele, retaining existing clientele, and your confidence in transferring clientele to the new associate are considerably increased. Do a less-than-stellar job of candidate selection, and you and your clients will quickly find out if you’ve made a poor decision. Consider the associates currently in your organization. How did they come to be employed by your practice? Did you select them? Did your partners select them? Did they come through any particularly well-thought-out method of talent acquisition? Are they the team you would choose if you had to do it all over again? Without a doubt, recruiting talent can be a bit of a crapshoot. But what are you doing right now, and throughout the year, to try and attract that next dynamic individual to your practice? Are you actively recruiting? Are you making contacts and networking to enhance your visibility? Are you making noise about your practice through the use of social media? Do you do anything beyond what every other practice does? Are you leaving recruitment to chance?

Likewise, when associates choose a practice for employment, there are a multitude of factors that feed into the decision-making equation: salary, location, type of practice, type of horses, type of clients, etc. At the top of these factors should be the existing team and personalities, the opportunity for mentorship under the brightest stars that the practice currently has, the plan for associate integration, the orientation and training process, and the focus on building the associate’s caseload. As much as it is the responsibility of the owner to select the candidates that can best complement the practice and drive it forward, it is the associate’s responsibility to understand their own strengths and what they bring to the table, where they see themselves adding value, and how they will enhance the current offering of the team.

When selecting an associate, fulfilling the needs of the practice can be complex. There are a multitude of drivers that mask themselves as needs. Take into consideration the needs of the day; perhaps you
are short a veterinarian or two when it comes to scheduling emergency coverage. Maybe you have a physical location of your practice area that could be served better if just one more veterinarian were on staff and ready for the challenge. You might even have a facility that is driving the need for a surgeon or an internist to create a spark in top-line revenues that would justify the cost of the monthly overhead you are currently experiencing. All of these are drivers. They are daily pains that cause you to seek out relief for the needs of the moment. But are they in alignment with where you are really trying to go? Unsuccessful people make decisions based on current circumstances, while successful people make decisions based on where they desire to be.2

The reality is that a successful exit strategy through the transfer of ownership to an associate, begins with a successful entrance strategy for that associate. To coin a phrase from Dr. Stephen Covey, we must “begin with the end in mind.”2 When was the last time you hired an associate with the idea that this could be the next owner in your practice? When was the last time you looked at an intern with that mindset? Proper cultivation of the next generation of owners in your practice begins during the recruitment phase and should be an active part of your decision-making process when hiring new veterinary personnel. This is not to say that every associate you hire must meet your criteria for future ownership, but make it part of the overall picture so that you keep the end goal fresh in your mind.

Setting Expectations

Expectations can only be met when everyone understands what is required of them. If an associate is to succeed, if they are to “win” in their new environment, they need to know what a “win” looks like. If ownership transition is a priority to your practice, and you feel that you are recruiting with that mindset, talk to your new associates about it as early as possible. It will change the entire dynamic of the relationship. When you are on the right track, it will change your level of commitment to that associate as well, in terms of time, attention, and mentorship. Your investment in their development will skyrocket. This will pay dividends in many ways, even if they don’t end up becoming an owner in your practice, the benefits they will receive from your mentorship will reciprocate value back to the practice in terms of the way they are able to deliver as a producing veterinarian.

Associates should understand what is being asked of them in several ways, be it the level of production they are to achieve, a leadership role they are to assume, or the amount of new business they are expected to generate, at the end of the day the associate needs to understand how they are being measured both for current job performance and future partnership opportunities.

Although there is no definitive industry standard for ownership parameters or requirements, practices often identify a timeline consisting of the years the associate must be with the practice, usually at least 2 or 3, the level of production the associate needs to attain, the number of days per year that owners must be willing to work in the practice (usually a minimum number of days off is determined so that existing owners are required to continue to contribute at a certain level). And the level of ownership that is available, for example, you may indicate that the first level of ownership is no more than a 25% interest in the practice, and that the remaining interests are to be purchased at certain time-frames depending on the number of existing owners in the practice, the available interest for transfer, and the timeframe for the exiting owner.

Business Training

Taking on a business partner means bringing new ideas and fresh perspective into the decision-making matrix of your practice. Both the existing owner and the new partner will want to make sure that there has been some foundational level of business training prior to the venture. Veterinary schools do not largely focus on the business aspect of veterinary medicine; therefore, anyone with an interest in increasing their business acumen is left to either figure it out as they go, or acquire some level of expertise in some other way. Online MBAs and business courses are readily available to anyone and can be an incredible asset if approached with the end goal of the business training in mind. Industry business offerings are also readily available through veterinary association CE, pharmaceutical-sponsored courses, and industry-specific customized courses that are designed specifically for certain aspects of the veterinary community. Be sure and get feedback from multiple sources about the value of each effort prior to engaging yourself or an associate in any of these efforts so as to best align your needs with the offering. Ultimately, however, what you are after is a partner who can bring more to the table than simply a check and an opinion. You’ll need powerful partners to achieve powerful results. Know the strengths and weaknesses of the associates you have recruited so as best to position them within the partnership to create the greatest synergies and make the addition of a partner just that ... a plus.

Understanding Your Practice’s Financial Picture

Your practice is a business and as such it is influenced by multiple factors that affect the overall financial health of the organization. Your understanding of your finances and the grasp you have on the pressure points that impact your financial health will be vital to your ability to transfer ownership. You need to know what you are selling, and you need to be able to talk about it with confidence. The utilization of consultants, ac-
countants, and financial advisors may be money well spent, but only if it empowers you to become a better business person. You want translational relationships with your advisors, not merely transactional relationships.1

Having a clear picture of your monthly, quarterly, and year-end financials will help you understand your expenses, your profitability, your net worth on a balance sheet, and better equip you to manage cash day to day. Most veterinarians focus on the top-line revenues, but even if you earn $1,000,000, it is a step in the wrong direction if you are spending $1,000,001. Controlling expenses, managing debt, and keeping the necessary cash on hand to manage the day-to-day flow of money is an art and will take time to truly master. Nobody wants to buy into a poorly managed practice. Poor management and a lack of understanding of your financials will be evident in your discussions with future owners. It will breed a lack of trust and likely doom your efforts from the outset. Equip yourself with the necessary tools or surround yourself with the right people to accurately track your revenues and expenses so that a true picture of your financial health is readily available to support your buy-in discussions.

Understanding Practice Value
Practice value and the method of determining that value will be a key discussion point. It is vital to both you and the incoming partner to have a solid grasp on the financial outlook so that everyone can make a good decision. Associates looking to buy into a practice are generally younger than existing owners, which means they are more recently removed from the costs of veterinary education, likely have student loans, and may have young families to support. Bottom line, a significant investment in a partnership opportunity requires careful financial analysis so that the purchase isn’t overly burdensome to the new partner. The last thing you want is a new partner with buyer’s remorse, wishing he or she could go back to just taking home a guaranteed wage. Painting a realistic financial picture is crucial, and practice value should be central to your discussion.

There are a number of ways that practice value can be determined. Typically this language is included within the existing partnership agreement. Industry norms suggest the use of a certified appraiser who has had experience appraising at least three practices similar in organizational structure and size to your practice. The National Association of Certified Valuators and Analysts accredits individuals who have an interest in this field and should be a designation that you should look for when searching for a qualified practice appraiser. Within the veterinary industry, Vet Partners is a group of consultants and business professionals that can be a resource for locating a certified appraiser that is familiar with your industry. Specifically, an equine practice appraiser should be sought out as the differences in equine and companion animal veterinary practices can be impactful to the final determination of final value.

Valuations are subjective, meaning the opinion or experience of the valuator will have an impact on the method of valuation they select, and the weight they give to the various factors that influence the overall value. Many aspects are taken into consideration to determine value including the veterinarians involved, the remaining lifespan of their useful careers, their current level of production and their expected production in the coming years. Existing equipment and its remaining lifespan will be analyzed, anticipated revenues, expenses, and their effect on the earnings before interest, taxes, depreciation, and amortization. Long-term debt of the practice debt will also be a key consideration.

A fresh valuation every 3 to 5 years can give you a consistent baseline of value so that you know with certainty the numbers you are dealing with. In addition, going through the process of a valuation will educate you as to the aspects of your practice that are key areas of consideration when determining value. The more familiarity you have with this process, the more confident you will become when discussing the buy-in process with your associates.

The Partnership and Buy/Sell Agreement
If you have an existing partnership agreement, be sure and examine it for its existing rules of ownership, and the rules of transferability as it relates to ownership interests. These will be key areas as you ready your practice for a transition. If you don’t have an existing partnership agreement, or are a sole owner, seek the input of an attorney who specializes in corporate law and understands your industry. Such input can give you useful information as you structure the guidelines of the organization you want to grow into. Partnership agreements and Buy/Sell agreements are just that—they are agreements. You need to understand what you are agreeing to and be reminded of the things that you might forget.

Specific to rules of transferability will be triggering events resulting from changes in the partnership brought on by “QRFDDD.” This stands for Quits, Retired, Fired, Divorce, Disabled, and Death.3 These triggering events give rise to ownership interest purchases and should be well understood before entering into a partnership agreement. If an existing partner quits working for the company or is fired or forced to resign, do you really want to keep them involved as an owner of the business? If they experience a divorce and their ownership interest becomes community property according to the state, do you want to have to deal with a potentially unfriendly spouse? If they are injured and are unable to work, unable to contribute to the revenues and production of the practice, will they remain involved as an owner, or will you have insurance available to buy out their interest? Although the most unlikely
to happen, if an existing owner dies, despite the difficulties of losing a key figure in the organization, life insurance policies should be sought to purchase the deceased owner’s shares and prevent an unnecessary financial impact to the practice. All of these questions and factors should be carefully considered and well understood as the prospect of creating or expanding existing partnerships is explored.

Another area of importance to the partnership and Buy/Sell agreement is that of the non-compete. Rules surrounding restrictive covenants vary from state to state, but nearly all support the enforcement of some level of non-compete language between partners. Be sure you understand what is reasonable for your state and your profession in terms of scope, geographic range, and duration. The last thing you’ll want is an exiting partner to create future competition for a business interest that you paid good money to acquire.

If you have an existing partnership agreement, be sure and pull it out and have it reviewed so that the areas of transferability, determination of value, pricing, and restrictive covenants are well understood. These are areas of significant depth and importance and must be well understood by existing owners and future owners alike. Comfort and ease in the conversation surrounding these areas will only lead to stronger relationships as all doubts and confusion are put to rest. Ultimately, that is what you should strive for as you move along the road to a useful and productive associate buy-in.

Accountability to Your Plan

The purpose of having a roadmap is to give you guidance, point out the areas of importance, and hopefully help you avoid some troublesome areas along the way. Equally as important as the guidance it offers, is the accountability that the plan inadvertently creates. In other words, when you begin the recruitment process with, “I’m looking for potential future owners” in mind, you make your desires known. You may even ask the question in an interview, “What are your thoughts/hopes regarding future ownership opportunities?” This doesn’t obligate anyone, but it plants the seed. Don’t ask the question if you aren’t genuinely interested in eventually bringing on an associate. While you’re not obligated, both you and the new associate will be aware that you asked the question. You need to mean it. As you move through the phases of a new hire to a 2-year associate, the mentorship aspect becomes more than a thought, it is the natural next step in the process. You started the relationship with the end in mind and as a result you begin acting in accordance with that end result which requires that you follow through on several of the required building blocks. Helping the associate build a caseload and promoting them as a vital piece of your practice is no longer, “a supportive thing to do.” It is a necessary part of the transition. Likewise, the business training, understanding of practice financials, practice value, etc., are all necessary pieces of a larger plan that has not only been talked about, but requires being acted upon, at the appropriate intervals throughout the course of the relationship. In short, once you have made the decision and start down the path you become accountable by virtue of making your goals public. This can be a positive force in eventually realizing what you set out to achieve.

You may have heard the old saying that what gets measured gets managed. You may have even heard that what gets managed gets improved. But you can measure and manage from a closet. The things that really get momentum are those things that are communicated, the things that are widely known. That is when accountability takes shape and its influence can create change in a positive direction. When performance is measured, performance improves. When performance is measured and reported, the rate of improvement accelerates.

Practice ownership and the potential of a future transition doesn’t always need to be a closely guarded secret. Many owners steer clear of the conversation, holding the topic close to their chest, fearful of setting themselves up for uncomfortable conversations. This is largely due to the unknown and not having all of the relevant information at hand to effectively communicate their position. Yes, it can take time to truly know if you want to bring on an associate as a partner. However, being decisive, maintaining communication throughout, and openly giving honest feedback will put both the associate and the owner in good stead in the long run in terms of accountability and will avoid any false expectations on anyone’s behalf.

3. Conclusion

Your practice is many things. It is a profession, a lifestyle, and a legacy. If managed correctly it can also be a very profitable business providing a reliable and abundant source of income for you and your family throughout the lifespan of your career and into your retirement. Whether you are an associate contemplating practice ownership, or an existing owner considering a partner (or more partners), the roadmap to making it a successful transition can be wrought with obstacles and difficulties. These troublesome areas can be avoided, or at minimum overcome, by deciding early on what it is you expect to realize from your involvement with a veterinary practice. In your moments of decision, your destiny is shaped. What you do today has an impact on tomorrow. By having the end result in mind, both associates and owners are better equipped to approach the recruitment process, pursue intentional mentorship, seek out business training, and arm themselves and their practice with the financial and
legal knowledge to better position themselves for a successful transition into ownership.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.

References
2017 American Horse Council Economic Impact Study

Amy L. Grice, VMD, MBA

In 2017, the American Horse Council conducted a series of surveys through The Innovation Group to explore the economic impact of the United States’ equine industry. Key findings included a current estimated national horse population of 7.2 million and 38 million equine enthusiasts. A total of $122 billion in spending can be attributed to the direct, indirect, and induced activities of the industry. Author’s address: PO Box 192, 320 Crittenden St., Virginia City, MT 59755-0192; e-mail: amyvmdmba@gmail.com. © 2018 AAEP.

1. Introduction
The American Horse Council (AHC), organized in 1969, works as an advocate for the interests of the United States equine industry. As a part of that advocacy, the organization periodically conducts studies to gain broad knowledge of the economic and demographic aspects of the industry. The most recent of these was conducted in 2017, and a report on the findings was issued in early 2018. The following material provides an overview of the AHC report “Economic Impact of the U.S. Horse Industry.”

2. Study Methodology
The 2017 study was conducted by The Innovation Group and consisted of two surveys performed on the Qualtrics platform. The first study, called “The Balanced Start,” gathered information from 3,284 respondents that were chosen to be demographically representative of the U.S. population. This allowed statistically valid inferences of horse ownership, participation in equine-related activities, and spending by spectators at horse-related events. The second study, termed the “AHC Association Survey,” was distributed to horse owners through various breed and other equine associations as well as the AHC. Complete membership lists of the participating organizations received e-mail links for the internet-based survey. Paper surveys were provided to those associations that requested them. This survey yielded 12,854 fully completed responses and allowed the characterization of association members and horse ownership in some detail.

In addition, separate surveys were conducted of equine rescues, competition event organizers, equine-assisted therapy operations, and equine academic programs to determine their economic contributions. For other industry segments, private financial data was requested or publicly available figures were used.

3. Study Results
In 1920, when horses were a common means of transportation, the number of horses in the United States was 25 million. Just forty years later, the horse population had declined to 3 million. Two breeds became dominant, with the 2,000 Thoroughbreds born in 1920 increasing to a foal crop of 50,000 by 1990, and the number of registered Quarter
Horses increasing from just 600 to 2.6 million by 2010. By 2004, the number of U.S. horses had rebounded to 9 million. Current estimates of the number of U.S. horses vary from 6 million (Brakke study 2014) to 8.9 million (AVMA AAEP Equine Economic Impact Survey 2016) to 7.2 million (AHC 2017). The 2017 AHC study found that the top three states, in order of horse population, were Texas, California, and Florida.

Of the equines, Quarter Horses were estimated at 2,137,000, the majority of which are used for recreation, followed by competition. Although almost half (506,000) of the 1,136,000 Thoroughbreds are used for racing, 401,000 are used for recreation. Standardbreds number 606,000, with a little more than half (332,000) used for racing. The most common use of the United Professional Horsemen’s Association breeds, comprised of American Saddlebred, Arabian, Friesian, Hackney, Morgan, and National Show Horses, is for recreation (532,000) followed by competition (216,000). All other breeds are estimated to total an equal number as the Quarter Horses, at over two million. See Table 1 for the estimated numbers of each breed used in each activity sector.

In contrast, numbers of mules and donkeys fell precipitously from 1920, when they numbered 5,432,391, to just 56,520 in 1987. However, a United States Department of Agriculture census in 2012 indicated that 292,590 mules and donkeys were present. The same census suggested a steep decline of horses during that time period.a

Although only 1.3% of the population of the United States owns horses, 29.2% of American households have members who participate in equine-related activities but do not own a horse, and an additional 13.2% spectate at horse events but do not own or participate. This 30.5% who own or participate represent almost one-third of households. Of the horse activity participants (nonowners), 38% are under 18 years of age. The median age of horse owners was 38 years, that of participants was 22 years, and that of spectators was 36 years in this study. The mean age of equine activity participants is lower than that of the U.S. population (38 years), and the difference is statistically significant. Among horse owners, 22% have income below $100,000 and 28% have income greater than or equal to $150,000.

The participants and spectators are estimated to have spent $27 million on expenses related to their participation in or attendance at equine events. These expenses include travel, dining, and lodging. Recreation with horses is popular; more than 10% of U.S. households have participated in trail riding and 8.4% have taken riding lessons.

The total value of economic impact of the nation’s horses equals $122 billion and 1,744,747 jobs. Direct effects total $50 billion and 988,394 jobs. Indirect and induced effects create the additional contribution.

Horse owners’ related expenses were investigated in this study and categorized as operating expenses or capital expenses. The different activity sectors varied widely in the amount they spent per horse. In addition, those respondents that did not belong to an equine-related association spent significantly less than those who did. Nonassociation members spent an average of total expenditure of $3,396. See Table 2 for further details.

4. Conclusion

The results of the 2017 AHC study are encouraging for the future of the equine and equine veterinary industries. Horses remain iconic and popular among the general population and hold a special place in the hearts of Americans. The equine industry provides significant economic benefit to each community in which it thrives. The data are sug-

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### Table 1. Horse Population Estimate by Breed and Sector (000s)

<table>
<thead>
<tr>
<th>Breed/Activity Sector</th>
<th>Racing</th>
<th>Competition</th>
<th>Recreation</th>
<th>Work</th>
<th>Other</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quarter Horse</td>
<td>245</td>
<td>416</td>
<td>929</td>
<td>281</td>
<td>266</td>
<td>2,137</td>
</tr>
<tr>
<td>Thoroughbred</td>
<td>506</td>
<td>164</td>
<td>401</td>
<td>14</td>
<td>51</td>
<td>1,136</td>
</tr>
<tr>
<td>Standardbred</td>
<td>332</td>
<td>6</td>
<td>180</td>
<td>3</td>
<td>87</td>
<td>606</td>
</tr>
<tr>
<td>UPHA Breeds</td>
<td>88</td>
<td>216</td>
<td>552</td>
<td>181</td>
<td>57</td>
<td>1,075</td>
</tr>
<tr>
<td>All Other</td>
<td>54</td>
<td>425</td>
<td>1,099</td>
<td>60</td>
<td>499</td>
<td>2,137</td>
</tr>
<tr>
<td>TOTAL</td>
<td>1,224</td>
<td>1,228</td>
<td>3,141</td>
<td>537</td>
<td>959</td>
<td>7,090</td>
</tr>
</tbody>
</table>

*a UPHA breeds are American Saddlebred, Arabian, Friesian, Hackney, Morgan, and National Show Horse.

### Table 2. Per-Capita Horse Related Expenses and Investments in 2016 of Association Members

<table>
<thead>
<tr>
<th>Activity Sector</th>
<th>Racing</th>
<th>Competition</th>
<th>Recreation</th>
<th>Work</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating Expenses</td>
<td>$21,751</td>
<td>$18,186</td>
<td>$4,774</td>
<td>$7832</td>
<td>$4,447</td>
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<tr>
<td>Capital Investments</td>
<td>$7,626</td>
<td>$6,053</td>
<td>$1,937</td>
<td>$197</td>
<td>$197</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$29,377</td>
<td>$24,239</td>
<td>$6,710</td>
<td>$8,029</td>
<td>$4,643</td>
</tr>
</tbody>
</table>
gestive that the deeply negative effects of the recession of 2008–2009 have receded.

**Acknowledgments**

**Declaration of Ethics**

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

**Conflict of Interest**

The Author provides veterinary business consulting services and earns income through veterinary business educational offerings.

**Footnote**

Results of the Merck Animal Health Veterinary Wellbeing Study

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1. Introduction
Terms like “burnout,” “depression,” “compassion fatigue,” and “stress” have been appearing with increasing frequency in veterinary journals. Some articles have suggested that veterinarians have an elevated risk of mental health problems and suicide.

To more fully understand the mental health status of veterinarians and what, if anything, could be done to address it, Merck Animal Health engaged Brakke Consulting, in collaboration with the American Veterinary Medical Association, to conduct a major study of US veterinarians.

The goals of the Merck Animal Health Veterinary Wellbeing Study were the following (1): to definitively quantify the prevalence of mental illness in the veterinary profession, (2) identify at-risk segments and contributing factors, and (3) suggest interventions or remedies that individuals and organizations could take to address any problems identified.

To design the research, Brakke and Merck Animal Health assembled a team with expertise in psychology, social work, veterinary medicine, and survey research. The American Veterinary Medical Association (AVMA) provided a sample of 20,000 names and email addresses from its database of working veterinarians. A survey was conducted in November 2017. As an incentive, participants were invited to enter a drawing for 20 $100 gift cards. In addition, researchers offered to contribute $1 to the American Veterinary Medical Foundation for each response. The study generated 3,540 completed surveys, for a response rate of 17.7%. The margin of error at the 95% confidence level was 1.62%. Respondents represented owners and associates in all types of practice, as well as employed veterinarians working in positions other than practice.

The mental health of respondents was measured using the well-established Kessler Psychological Distress Scale. Kessler determines the presence or absence of severe psychological distress or mental illness by using a numeric score. Wellbeing was measured using an index based on three questions widely used to measure wellbeing. Wellbeing goes beyond the presence or absence of mental illness and measures how people feel about their lives compared with the best or worst they can imagine. Results for veterinarians were compared to the US general population of employed adults by using data from the University of Michigan’s Panel Study of Income

NOTES
Dynamics (PSID) and the National Institutes of Health. Begun in 1968, PSID is the longest-running longitudinal study in the world and consists of a nationally representative sample of 18,000 adults in 5,000 U.S. households.

The Merck Animal Health Veterinary Wellbeing Study explored the impact of various factors that can influence mental health or wellbeing, including student debt, overall financial health, work hours, social and marital status, attitudes towards job, work-life balance, participation in healthy activities, personality, and other attributes.

Key Findings

- An initial question in the survey established that veterinarians consider student debt, stress, and suicide as the three most critical issues facing the profession.
- Veterinary medicine is a stressful profession. Two thirds of veterinarians, including 79% of associate veterinarians in practice, reported experiencing feelings of depression, compassion fatigue or burnout, and/or anxiety within the last year.
- Overall, 5.3% of veterinarians experienced severe psychological distress or mental illness within the past 30 days. This is consistent with the 4.7% reported in PSID for the general population. However, the 5.3% is lower than that reported for veterinarians in other, non-representative studies.
- Younger veterinarians (<45 yr) were much more likely to suffer severe psychological distress than older veterinarians (Fig. 1). The prevalence of serious psychological distress was generally consistent across practice types except for food animal practice, where it was low to nonexistent.
- Work-related factors most often associated with severe psychological distress included working long hours, having student debt, working as a relief veterinarian, and working more or fewer hours per week than desired. Interestingly, it was the presence of student debt, not the amount of it, that was most associated with serious psychological distress.
- Only half of veterinarians with severe psychological distress were receiving treatment. In addition, only 16% of those psychologically distressed were taking advantage of resources available from professional organizations,
most commonly AVMA and Veterinary Information Network.

● 25% of veterinarians had thought about suicide at some time in their lives. This was higher than seen in other studies. However, only 1.6% of respondents had attempted suicide, lower than in the general population (5.1%).

● Veterinarians’ score was somewhat lower in wellbeing than the general population. However, older veterinarians scored much higher than their counterparts in the general employed adult population and younger veterinarians much lower. Owners scored higher in wellbeing than associates in practice (Fig. 2). To demonstrate the difference between mental health and wellbeing, only 28% of those who were “suffering” from a wellbeing perspective were also experiencing severe psychological distress, as measured by the Kessler scale.

● Work-related factors most often associated with high levels of wellbeing included higher income, working fewer hours, not working evenings, having little or no student debt, and being owner of a practice.

● Of concern, only 41% of veterinarians would recommend a career in veterinary medicine to a friend or family member; 33% would not recommend it and 26% were unsure. That compares to 70% in the general population who would recommend their career and 51% of physicians (Fig. 3). Only 24% of veterinarians <35 years of age would recommend the profession. The reasons most often given for not recommending the profession include low compensation (54%), high student debt (54%), and the personal toll the profession takes (44%)

Reducing Severe Psychological Distress and Improving Wellbeing
Those veterinarians without severe psychological distress, as well as those with high wellbeing, were much more likely to participate in healthy activities (Fig. 4).

Nonwork factors contributing most to high wellbeing and sound mental health included the following:

● Spending time with family.
● Socializing with friends.
● Traveling and reading for pleasure.
● Having a hobby.
● Exercising.
● Being married or in a relationship.

The study also found that spending more than one hour a day on social media was negatively associated with good mental health and a high level of wellbeing. In fact, those with severe psychological distress were more than twice as likely to spend more than two hours a day on social media. Limiting time on social media such as Facebook or Instagram or taking a periodic sabbatical from such activities seems prudent.

Given the high level of stress inherent in the profession, it would behoove veterinarians to consult with a mental health professional to develop a stress management plan. Likewise, working with a certified financial planner could assist in developing a plan to manage student debt and living expenses within the limits of one’s income.

It is important that employers recognize the issues common in the profession and acknowledge it to employees. Providing time off for appointments with mental health professionals, financial planners, and similar counselors is important. Offering an Employee Assistance Program with mental health counseling benefits would be particularly valuable.

Ultimately, it is important that professional veterinary organizations and veterinary colleges work to reduce the cost of veterinary education through scholarships, low-cost loans, loan forgiveness, and other support. In addition, colleges of veterinary medicine could make the services of on-campus counselors available to alumni. College and professional organizations should also explore novel alternatives such as online or tele-behavioral health counseling to improve the availability and lower the cost of mental health services.

Acknowledgments

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

Conflict of Interest
The Author has no conflicts of interest.
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