

American Association of Equine Practitioners

PROCEEDINGS



63RD ANNUAL
CONVENTION

November 17-21, 2017
San Antonio, Texas



Proceedings of the 63rd Annual Convention of the American Association of Equine Practitioners

**San Antonio, Texas
November 17–21, 2017**

Program Chair: Margo L. Macpherson, DVM, MS, DACT

ACKNOWLEDGMENTS

**Phoebe A. Smith, DVM, DACVIM, Educational Programs Committee Chair
Carey M. Ross, Scientific Publications Coordinator**

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Policy Statement

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

Mission Statement

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

Future AAEP CE Dates

2018	Resort Symposium	Maui, Hawaii	January 29–31
2018	Focus on Ambulatory Practice	Raleigh, North Carolina	June 25–27
2018	Focus on Integrative Imaging	Raleigh, North Carolina	June 25–27
2018	360° on the Problem Mare	Fort Collins, Colorado	September 16–18
2018	64 th Annual Convention	San Francisco, California	December 1–5
2019	65 th Annual Convention	Denver, Colorado	December 7–11
2020	66 th Annual Convention	Las Vegas, Nevada	December 5–9
2021	67 th Annual Convention	Nashville, Tennessee	December 4–8

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 Antonio 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 author(s). Content is scored using the criteria of Study Design, Study Quality, Innovation and Impact, Practicality, and Manuscript Quality. This year 164 papers were submitted for the 55 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 Antonio program, so please thank them for all their hard work creating this program for you.

From Your President



American Association of Equine Practitioners
4075 Iron Works Parkway • Lexington, KY 40511
859.233.0147
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www.aep.org



Dear AAEP Members & Guests:

Welcome to San Antonio and your 63rd Annual Convention. AAEP strives always to produce world-class continuing education and this year is no exception. Your President-Elect and Program Chair, Dr. Margo Macpherson, and the Educational Programs Committee under the direction of Chair, Dr. Phoebe Smith, and Vice-Chair, Dr. Charlie Scoggin, have put together an outstanding program with varied opportunities to suit every member. Many thanks to this team and the many speakers they have on board.

It has been my privilege to represent you and our organization at many events throughout this year and I can assure you that AAEP's input is sought and respected throughout the equine world. The work of so many members results in AAEP being the voice of authority for the horse. That is our shining goal.

While here in San Antonio you will gain new knowledge, hear how your organization is meeting the goals of our strategic plan, discuss many issues of concern to equine veterinary medicine and our profession as a whole, catch up with old friends and hopefully have fun doing all of it.

Please take time to visit the Trade Show and thank our many exhibitors and in particular, our Educational Partners and Sponsors. Their support for the AAEP is a crucial part of our ability to continue to provide such high quality continuing education.

The AAEP Foundation once again presents its Foundation Celebration but I hope you will get to know your Foundation better as this arm of AAEP is set to attain new heights. We have new and expanded scholarships for students as well as benevolence grants and now we are moving towards more research funding. This is an exciting progress.

Again, thank you for the opportunity to represent you this year and have a great convention.

R. Reynolds Cowles, Jr., DVM
AAEP 2017 President

From Your President-Elect and Program Chair



American Association of Equine Practitioners
4075 Iron Works Parkway • Lexington, KY 40511
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www.aep.org



Welcome AAEP members, students and guests to the 63rd AAEP Annual Convention in San Antonio, TX! As the 2017 Program Chair, I am pleased to offer you an excellent educational program amidst the colorful sights and sounds of San Antonio, TX.

This program could not have been organized and completed without the 50 Educational Programs Committee members, led by Chair Dr. Phoebe Smith and Vice-Chair Dr. Charlie Scoggin. The Educational Program committee members were tireless in their efforts to present a high quality and balanced meeting for our broad range of member interests. Thousands of hours were spent reviewing over 160 abstracts and invited papers for scientific content, timeliness, and practicality. Mrs. Carey Ross orchestrates the review, selection and publication process and provides a level of expertise in program planning that is unsurpassed. It is through her efforts that this exceptional program has come together.

Some Convention highlights you won't want to miss include:

- **Keynote Speaker:** Nigel Marsh, one of the world's most sought-after experts on work/life balance, will kick off the meeting with his talk "How to Make Work/Life Balance Work – A Modern Day Unicorn for Losers or Something Life Changingly Fabulous Available to All?"
- **Kester News Hour:** Drs. Liz Santschi, Robert MacKay, and newcomer Regina Turner will take the stage after the Opening Session to update and educate us on the latest veterinary research and equine news topics.
- **Milne Lecture:** Dr. Paddy Dixon, world renowned expert in equine dentistry and Professor of Equine Surgery at the University of Edinburgh, will share information on the evolution of horses and equine dentistry.
- **In-Depth Sessions:** We'll go "in-depth" examining laminitis, upper respiratory issues, reproductive management of the performance mare, and pulmonary disease in the athletic horse during these half-day sessions. Some will use the FXP interactive system whereby attendees can respond to presenter's questions using their smartphone or other personal device.
- **How-to Sessions:** Three half day sessions present practical information and techniques on how to handle those difficult cases we face in ophthalmology, endoscopy, and how to have a happy equine patient with health care procedures.

Other Sessions not to miss are Basic to Basics: Making the Most of Ultrasound in Equine Practice; Judicious Use of Antimicrobials; Identification, Traceability and Biosecurity; Ethics; and Balancing Work and Personal Life.

- **Business Education:** Four half day sessions with the theme "Back to Basics" are geared to help you manage your practice and personal life.
- **Trade Show:** Our trade show is expansive as always with a broad array of the most current equine veterinary products. Be sure to take a moment to thank all of our educational partners for their efforts on behalf of AAEP and its members.
- **Table Topics:** The always popular small group interactive sessions will be back in full force with many of your old favorites as well as some new topics. The Educational Programs Committee strives to rotate experts with different perspectives to moderate these topics each year so that the discussions remain fresh.
- **Foundation Celebration:** The 2017 Foundation Celebration will be offered off site this year at the popular Knibbe Ranch in the hill country of Texas. Be ready to join your friends for a night dancing and fun with the music of Dale Watson, silent and live auctions and other "Texas-style" activities.

This is the world's largest continuing education event for equine practitioners and I hope you have a fun learning experience.

Sincerely,

Margo L. Macpherson, DVM, MS, DACT
2017 AAEP President-Elect

Raising the Standard in Horse Health

2017 AAEP Board of Directors

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DACVSMR

2018

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2017 AAEP Awards

Distinguished Life Member – Dr. Harry W. Werner

The AAEP Distinguished Life Member designation is awarded to a member in recognition of outstanding contribution to the association throughout their career.

Distinguished Educator Award (Academia) – Dr. Peter Timoney

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.

Sage Kester Beyond the Call Award – Dr. Nancy Collins

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.

The Lavin Cup: The Equine Welfare Award of the AAEP – Ryerss Farm for Aged and Retired Horses

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

General Instructions for Authors

64th AAEP Convention

San Francisco, CA

December 1–5, 2018

To submit a paper, go to <https://aaep2018.abstractcentral.com>

ALL papers must be submitted online by March 15, 2018, 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. Doses should be expressed entirely in metric units and with specific time intervals.

Example:
22 mg/kg, q 12 h, IV (not 10mg/lb, BID, IV)

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-amav.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:

Auer JA, Martens RJ, Williams EH. Periosteal deformities in foals. *Am J Vet Res* 1982;181:459–466.

Murphy CJ, Lavoie JP, Groff J, et al. Bilateral eyelid swelling attributable to lymphosarcoma in a horse. *J Am Vet Med Assoc* 1989;194:939–942.

Some common journal abbreviations include: *Acta Vet Scand*, *Am J Vet Res*, *Can J Vet Res*, *Can Vet J*, *Cornell Vet*, *Compend Contin Educ Pract*, *Equine Vet J*, *Equine Vet J Suppl*, *J Am Vet Med Assoc*, *J Vet Diagn Invest*, *J Vet Intern Med*, *Prev Vet Med*, *Vet Clin North Am Equine Pract*, *Vet Radiol*, *Vet Rec*, *Vet Surg*. Other journal names should be abbreviated in accordance with the National Library of Medicine and *Index Medicus*.

Book:

Turner AS, McIlwraith CW. *Techniques in large animal surgery*. Philadelphia: Lea and Febiger, 1982;186–191.

Banks P, Bartley W, Birt LM. *The biochemistry of the tissues 2nd ed*. London: John Wiley & Sons, 1968;24.

Devlin TM, ed. *Textbook of biochemistry with clinical correlations*. New York: John Wiley & Sons, 1982;14–36.

Chapter in a book:

Axelrod B. Glycolysis. In: Greenberg DM, ed. *Metabolic pathways, vol 1. 3rd ed*. New York: Academic Press, 1967; 112–145.

Kainer RA. Functional anatomy of equine locomotor organs. In: Stashak TS, ed. *Adams' lameness in horses 4th ed*. Philadelphia: Lea and Febiger, 1987;12–18.

Proceedings:

Divers TJ. Acute renal failure in horses and cattle, in *Proceedings*. 3rd Am Coll Vet Int Med Forum 1985;93–95.

Lamb CR, Koblik PD, O'Callaghan MW, et al. Comparison of bone scintigraphy and radiography as aids in the evaluation of equine lameness: Retrospective analysis of 275 cases, in *Proceedings*. *Am Assoc Equine Pract* 1989;35: 359–368.

Footnotes:

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

Jones CD. The selective advantage of the ABO blood groups [thesis]. Ithaca, NY: Cornell University; 1990.

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

Smith AB. Unpublished data. January 1990.

Evans LH. Entrapment of the epiglottis. *Am Assoc Equine Pract*. In Press 1981.

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

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

Example:

All horses were sedated with a combination of detomidine HCL^a (10-20 mg/kg IV) and butorphanol tartrate^b (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:

Tables 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, 2018, 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://aaep2018.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.

Scientific Papers: Guidelines for Authors 64th AAEP Convention San Francisco, CA December 1-5, 2018

**To submit a paper, go to
<https://aaep2018.abstractcentral.com/>**

ALL papers must be submitted online by March 15, 2018, 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.

The “How to” Paper: Guidelines for Authors 64th AAEP Convention San Francisco, CA December 1-5, 2018

**To submit a paper, go to
https://aaep2018.abstractcentral.com**

ALL papers must be submitted online by March 15, 2018, 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.

**Review Paper: Guidelines
for Authors
64th AAEP Convention
San Francisco, CA
December 1-5, 2018**

**To submit a paper, go to
<https://aaep2018.abstractcentral.com>**

**ALL papers must be submitted online by
March 15, 2018, 3:00 p.m. ET.**

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

Review papers should generally be formatted as described in the "Instructions for Authors of Manuscripts" except where otherwise noted here. The paper should be titled "Review of Some Subject." The content of review articles should

be organized with headings and subheadings that provide a logical flow to the material presented. A "Take Home Message" is required for a Review Paper. The Introduction should define the subject matter and put it in context, explaining why the review is necessary. The purpose of the review paper should be clearly stated in the Introduction.

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

An appropriately complete reference list should be included. The format for references is the same as that described in "General Instructions for Authors." Review papers should be no fewer than 600 words, with no upper word limit.

Illustrations should be provided in the format described in "General Instructions for Authors". If previously published material is submitted, including text, photographs or drawings, the author must acknowledge the original source and submit written permission from the copyright holders (author and publisher) to reproduce the material. This permission must accompany the original manuscript at the time of submission.

**Abstracts ≤ 250 Words:
Guidelines for Authors
For those who intend to publish in
a refereed journal
64th AAEP Convention
San Francisco, CA
December 1-5, 2018**

**To submit a paper, go to
<https://aaep2018.abstractcentral.com>**

**ALL papers must be submitted online by
March 15, 2018, 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 64th AAEP Convention San Francisco, CA December 1-5, 2018

To submit a paper, go to
<https://aaep2018.abstractcentral.com/>

ALL papers must be submitted online by March 15, 2018, 3:00 p.m. ET.

The general theme for the 2018 Business of Practice Sessions is "Practice Culture for Profitability." 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 "How to" papers are allotted a total speaking time of 20 minutes (15 minutes presentation time + 5 minutes questions). Other papers are allotted 25 minutes total. The following topic suggestions are intended to spark ideas that relate to the "Practice Culture for Profitability" theme. We also welcome paper submissions on any topic pertaining to the Business of Practice.

Potential Topics:

- Open book management -sharing with your employee's your success
- Fee's - how they are determined and how this relates to employees and associates having the conversation with the owner.
- Client/customer service, communicating value (invoices).
- Engaging associates in the leadership conversation and driving culture of the practice
- Employee engagement
- Using Practice software to increase client and employee compliance
- Utilizing personal and professional strengths to improve efficiency and practice profitability.

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ored 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. All submissions should strictly adhere to these Instructions for Authors.

Guidelines:

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

Headings may include (but are not limited to) the following:

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

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:

In circumstances where a medical error results in an adverse outcome, a thoughtful response on the part of the veterinarian, staff, and practice is required. This paper will review communication techniques for constructively responding to these difficult situations.

Introduction:

Significant published work should be acknowledged here. A clear statement of the business challenge, or the objective or purpose of the submission, should be included. The statement of objectives is usually found in the last sentence of the Introduction.

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.

Discussion:

Important findings documented in the solution or results of the study should be stated. Solutions or results can be related to other work that has been done and how the results differ. The practical take home message for the equine prac-

tioner 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.

Acknowledgments:

Acknowledgments should include financial and material support for research 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.) In addition, if the author provides veterinary business consulting services, or earns income through veterinary business educational offerings, this should be disclosed. A Conflict of Interest statement should be included in the paper under the Acknowledgements section whether a conflict exists or not.

Example of COI Statement

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

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

At the point of submission, the American Association of Equine 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?

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2. Any and all authors listed on the paper must disclose if no conflict exists
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References:

Submissions may include 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. Reference examples can be found in the General Instructions for Authors.

Footnotes:

References to personal communications and papers submitted but not yet accepted for publication should also be footnoted:

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.

Tables:

Tables should be self-explanatory and should supplement the text. Provide a concise, descriptive title for each table.

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Deadline:

ALL papers must be submitted online by March 15, 2018, 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:

Papers will be reviewed, scored, and selected by the Educational Programs Committee. Since the presentation ability of business speakers is crucial, the review for these papers requires a two-step process: 1. Initial acceptance of the paper while the author is blinded. 2. The process becomes unblinded before final selections are made.

This two-step review process was implemented to protect the association from selecting speakers whose presentations may have a strong commercial bend.

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.
- Any acknowledgments section should be removed from the blinded version. Also, please delete any notes that indicate affiliation, conference presentations, author or departmental websites, etc.
- Do not use author name or affiliation in the names of the submitted files.

Scoring Criteria:

The subject matter is relevant to the business operations of a veterinary business. How-to cases should be based upon personal experience in a veterinary business. Papers describing a business process should be applicable to an equine veterinary business and should be supported by references from business publications.

Pre-Press Approval:

Authors will have final approval at the page proof stage. Changes/updates 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. Please email Carey Ross (cross@aaep.org) to request a list of members in various areas of expertise who have agreed to volunteer their time to mentor an author who needs guidance.

“How to” Paper Submissions for Business of Practice Sessions:

“How to” papers are presented to describe and explain a technique or procedure that relates to the business of practice. The goal of these papers 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 should follow the same guidelines in this document, except where otherwise noted below.

The Title should begin with “How to . . .” and clearly identify the technique or procedure that will be presented.

A “Take Home Message” is not required for “How to” papers.

The Introduction should include why you use the technique. If there is a problem with the traditional methods or the currently used method can be improved, this should be explained.

The Materials and Methods section should explain exactly how the technique is performed so that another veterinarian familiar with the subject area could follow your example. You may use a step-by-step method for the paper and the presentation.

The Results section should include a summary of what happens when you use this technique. 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 is helpful 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.

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Diagnostic Evaluation of the Laminitis Case

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1. Introduction

A current understanding of the different types of laminitis is critical to the examination of not only animals at risk of laminitis, but any animal exhibiting lameness. Due to a rapidly increasing knowledge base regarding the different types of laminitis, we now have very few cases that cannot be placed in one of the three types of laminitis: endocrinopathic laminitis (including both equine metabolic syndrome-associated laminitis [EMSAL] and those associated with pituitary pars intermedia dysfunction [PPID]), sepsis-related laminitis, and most rarely in practice, supporting-limb laminitis. Endocrinopathic laminitis, the most common type seen by the ambulatory practitioner, has enjoyed the greatest knowledge gain in the past decade. Whereas it was a large step forward to identify the classic phenotype of horses at risk of endocrinopathic laminitis (i.e., the obese, cresty-necked horse or pony or the aging horse exhibiting PPID-related signs such as hirsutism), there were still laminitis cases that did not seem to fit well in these categories of endocrinopathic laminitis but also did not have the history or characteristics of sepsis-related or supporting-limb laminitis. The combination of advancements in our understanding of the role insulin dysregulation plays in all types of endocrinopathic laminitis, and the advancements in testing for insulin dysregula-

tion allowed larger studies to determine the horses at risk for endocrinopathic laminitis. It is now realized that, very similar to human metabolic syndrome, genetics likely plays as important a role as body condition in EMSAL. Therefore, there can be obese animals with normal insulin regulation that are of little risk of laminitis due to their individual genetics, and other horses that are of relatively normal body condition (i.e., “show shape”) that have both insulin dysregulation and EMSAL. Just as some human races are much more prone to metabolic syndrome than others, we realize that certain horse breeds (e.g., Morgans, Warmbloods, American Saddlebreds, many Latin American breeds [e.g., Criollo, Paso Fino]) and many pony breeds are at increased risk of equine metabolic syndrome (EMS). Thus, especially in these breeds, animals may exhibit insulin dysregulation and endocrinopathic laminitis without outward obesity. Whereas the disease is not as common in breeds such as Thoroughbreds and Quarter Horses, it certainly still occurs in these breeds (most likely due to a combination of individual genetics as well as obesity). It has recently been reported that, even in horses with PPID, the only ones at risk of laminitis are those with concurrent insulin dysregulation.¹ The culmination of this work results in the reality that, although many equids with EMSAL do have

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the classic presentation of being an at-risk breed suffering from obesity, many of a subset of animals that exhibit signs of laminitis but do not obviously fit into one of the three types are eventually diagnosed with insulin dysregulation (commonly via dynamic insulin testing) and thus can be classified as having endocrinopathic laminitis.

The other discovery in the last few years that greatly impacts our physical examination findings when evaluating the laminitis suspect is that, in sharp distinction to the rapid and severely painful failure of lamellar support (and resulting displacement of the distal phalanx [DP]) that commonly accompanies sepsis-related and supporting-limb laminitis, the lamellar changes and displacement of the DP in endocrinopathic laminitis commonly occurs in such a subtle and gradual fashion that the disease may go unnoticed until mild lameness due to soleal issues (e.g., bruising) seems due to pressure of the displaced DP on the soleal tissue.² Although there are still many cases of pasture-associated laminitis (part of endocrinopathic laminitis) in which the disease becomes obvious after exposure to a lush pasture, there are many horses that have a history consistent with performing well in different athletic endeavors while displacement of the DP was likely occurring, and the horse is brought to the veterinarian for a diagnostic evaluation of a mild bilateral forelimb lameness. Another advancement that has greatly aided in our diagnosis of more subtle cases is a large amount of literature setting better guidelines for radiographic identification of displacement of the DP.³

In general, there are three presentations associated with laminitis with which the veterinarian is confronted: 1) acute onset of a primary episode of laminitis, usually characterized by severe lameness, 2) the case of moderate lameness in animals with a known history of laminitis, and 3) the case of mild lameness of unknown origin (commonly bilateral forelimb lameness).

1) The Acute Onset of a Primary Episode of Laminitis with Severe Lameness

The acute onset of laminitis with severe lameness in affected feet is most commonly observed in cases of sepsis-related and supporting-limb laminitis. Because these animals have usually not previously had laminitis, the hoof wall usually appears normal in these animals. However, the animals are commonly exhibiting 1) an elevated heart rate, 2) warmth in the affected feet with prominent digital pulses, 3) treading of the affected feet, and 4) a moderate-to-marked resistance the veterinarian attempting to pick up a foot opposite to the affected foot. Whereas the disease affects either both front feet or all four feet in sepsis-related laminitis, the disease only affects one foot (the foot contralateral to a limb which the animal is unable to bear normal weight) in supporting-limb laminitis. In addition,

whereas laminitis commonly occurs 24 to 72 hours after the onset of systemic sepsis in sepsis-related laminitis, supporting-limb laminitis may occur within 3 days of severe lameness in the contralateral limb, or may not occur until 4 to 6 weeks of preferential weight bearing on the supporting limb. Once supporting-limb laminitis is present, there is most commonly catastrophic failure of the lamellae and rapid displacement of the DP. In a recent survey (performed by the author) of surgeons in private practice and teaching hospitals in the United States and Canada, the most common cause of supporting-limb laminitis was a septic tendon sheath or joint in the opposite limb. Whereas sepsis-related laminitis is most commonly secondary to severe gastrointestinal diseases (postoperative colon torsion, enterocolitis, etc.) in referral hospitals, it can be seen with relative frequency in practice (commonly within 48 to 72 hours) following grain overload or the onset of retained placenta/acute metritis. There are a number of cases of the pasture-associated laminitis component of endocrinopathic laminitis in which animals may exhibit acute and severe signs if suddenly exposed to an excessive amount of high-energy feed (commonly in the form of lush pasture). There is controversy about whether these acute exacerbations are actually due to endocrinopathic causes (i.e., an exaggerated insulin response) or whether the animals may consume enough carbohydrate to cause hindgut disturbance (similar to grain overload) leading to sepsis-related laminitis.

2) The Case of Moderate Lameness in Animals with a Known History of Laminitis

This type of presentation can occur in all three types of laminitis, with animals commonly presenting months to years after the initial episode of laminitis. A major difference is that there has usually only been one bout of laminitis in cases of sepsis-related and supporting-limb laminitis, and the lamellae are usually stable (and not the cause of pain) at the time of examination in these patients. The current lameness is usually due to subsolar pressure from displacement of the DP, which has not been adequately corrected since the original episode of laminitis. Whereas this presentation is also common with endocrinopathic laminitis, the major difference is that many of these animals—if not intensively managed nutritionally—have commonly suffered multiple bouts of laminar insult since the initial episode, and may have ongoing lamellar injury. Most of the horses with this presentation, regardless of the type of laminitis leading to it, have hoof wall changes from a chronic displacement (i.e., dishing of the dorsal wall if chronic capsular rotation). These animals rarely have the acute signs of laminitis (i.e., throbbing pulses, warm feet, treading of feet); they are commonly lamer when walked on a hard surface, especially in tight circles.

3) The Case of Mild Lameness of Unknown Origin (Commonly Bilateral Forelimb)

Due to the insidious nature of displacement of the DP and an associated insidious nature to subsequent lameness exhibited by the animals in endocrinopathic laminitis, it should be on the differential list of any lameness exam. As the forelimbs are most commonly affected in endocrinopathic laminitis, the disease should be high on the list in horses with bilateral forelimb lameness in which navicular disease/palmar heel pain is commonly the primary concern of owners and trainers. In an animal either exhibiting the characteristics of equine metabolic syndrome (obesity, hoof wall abnormalities), or responding in the toe region to hoof testers (rare for navicular disease), endocrinopathic laminitis should climb higher on the differential list. As it has now been well published that the palmar digital nerve block not only anesthetizes the heel but also anesthetizes the entire sole⁴ and vast majority of the hoof wall/lamellae,⁵ nerve blocks are not usually helpful in differentiating between palmar heel pain and sole or hoof wall/lamellar pain. The most accurate diagnostic technique is navicular bursal block/anesthesia; however, pain emanating from the dorsal aspect of the sole (common with solear pressure with displacement of the DP) is also anesthetized within 10 minutes of performing the navicular bursa anesthesia technique.⁶ Thus, whereas many practitioners concentrate on radiographic assessment of the navicular bone in horses with forelimb lameness, which responds to either palmar digital nerve blocks or navicular bursa anesthesia, assessment for displacement of the DP including radiographic measurements³ on lateral (and possibly dorsopalmar) views is important in these cases to assess for displacement of the DP indicative of a lameness resulting from endocrinopathic laminitis.

The Initial Exam

When first assessing a horse for laminitis, the initial treatment plan depends on an accurate history and preliminary general physical exam to determine both 1) whether the horse is truly suffering from laminitis, and 2) the severity and type of laminitis (e.g., sepsis-related vs. endocrinopathic vs. supporting limb) the animal is experiencing if it is present. The relevant history will include the timing (especially regarding season/forage available) and severity of lameness exhibited by the horse both recently and in the past, the animal's diet and body condition during the past year, any recent history of a bacterial infection in any organ that may lead to systemic sepsis (e.g., colitis, retained placenta, pleuropneumonia). In the animal in which signs of laminitis are limited to one limb, the history of a disease or injury causing lameness in the opposite limb is important. A physical exam is indicated to assess factors possibly putting the animal at risk for the different types of laminitis (i.e., obesity, fever, etc.).

The heart rate is extremely important to obtain initially.

Although the primary cause for an increased heart rate is pain due to laminitis, the clinician needs to make sure that it is not due to systemic causes related to systemic sepsis. The mucous membranes and rectal temperature are the easiest and fastest way to obtain an initial assessment of sepsis-related disease. With pink membranes and a normal rectal temperature (pain does not cause increased rectal temperature in most horses), any tachycardia is likely due to pain. Another test is, if nerve blocks are performed to obtain radiographs and examine the sole surfaces of the feet, to retake the heart rate post nerve block. In the author's view, the heart rate (if not complicated by sepsis) is the most valuable physical parameter regarding assessment of the horse's duress. Whereas heart rates in the range of 45 to 55 beats per minute are common with moderate pain in laminitis cases, heart rates in the 60s—and especially those in the 70s and 80s—are of great concern to the author not only regarding humane concerns but also prognosis.

The Lameness Exam

The lameness exam will vary greatly on the degree of lameness the horse is exhibiting. In the severely lame animal in which it is difficult to pick up a foot, no lameness exam is necessary. However, if temporary nerve blocks are performed on the front feet for initial assessment and treatment (discussed below), the horse can be walked a limited number of steps to determine whether there is involvement of the hindlimb digits. In the moderately lame horse in which there is a history of laminitis, a lameness exam is usually performed at a walk in a straight line and a figure eight both on a hard and soft surface to assess the relative degree of lameness in each limb (usually forelimbs). The author educates owners that horses that have suffered previous lamellar injury/DP displacement are commonly painful when torque is applied to the hoof capsule for the rest of the animal's life; circling or walking in a figure eight on a hard surface such as asphalt will always apply torque to the hoof capsule (especially the foot on the inside of the circle) due to the purchase of the hard surface on the solear surface of the hoof capsule. Thus, although we usually perform this procedure on a hard surface to assess the relative amount of pain exhibited on the different limbs, it is more important clinically to assess the animal on a soft surface in which there is more give of the ground surface and therefore less torque applied to the hoof capsule. In the mild lameness case in which endocrinopathic laminitis is a possibility, a more routine lameness exam at a walk and trot may be performed. However, it is best to perform any exam at a trot on a soft surface to avoid exacerbating any lamellar injury due to excessive impact on a hard surface.

Examination of the Digits

Examination of the digits includes an examination of the external hoof wall, the coronary band (including the integument proximal to the coronary band), and, importantly, the ground surface of the foot. In the acute, severe case of laminitis, the hoof wall is commonly normal due to the acute nature of onset of disease in supporting limb laminitis and sepsis-related laminitis. However, the hoof wall is much more likely to exhibit abnormalities in cases of endocrinopathic laminitis due to the disease commonly having a more chronic nature (months to years). The changes may include 1) dishing of the dorsal aspect of the hoof wall (due to capsular rotation of the DP) and 2) horizontal rings (commonly called "growth rings") likely correlating to exacerbations of the disease process over the past several months. A close visual examination of the coronary band may reveal separation from the hoof wall. It is important to document the degree of separation circumferentially, and the character of exudate from any separation. A focal region with a purulent exudate may suggest a "gravel" (an abscess that has traveled up the white line and ruptured at the coronary band), whereas hemorrhagic exudate commonly suggests a more serious cause, frequently emanating from extensive separation of the lamellar tissue (commonly with displacement of the DP). Finally, palpation of the tissue immediately proximal to the coronary band may reveal a "trough" where distal displacement of the aspect of the DP adjacent to that area has resulted in depression of the soft tissue. The location of either hemorrhage of the coronary band or a "trough" in the soft tissue may give some indication of the type of displacement: abnormalities dorsally commonly suggest dorsal rotation of the DP, circumferential abnormalities commonly occur with symmetrical distal displacement of the DP, and abnormalities primarily on one side of the foot (most commonly medial) may suggest asymmetrical distal displacement of the DP.

The solear surface is examined for any abnormalities including disruptions in sole, the integrity of the white line, and the health of the frog. In the horse in which the feet can be picked up to examine the ground surface without the use of nerve blocks, assessment of solear pain provides valuable information for diagnosis and management of the case. Digital pressure (with the clinician's thumbs) is first applied around the entire sole to detect either pain or palpable evidence of a thinned sole or underlying seroma. If the sole palpates to be relatively intact, hoof testers can be applied to the digit to further assess areas of pain. Hoof testers should not be placed on areas of sole that palpate to be abnormal on digital pressure as they may result in injury/perforation of the sole. The areas of pain are not only important for obtaining a full clinical picture of the distal displacement of the DP (i.e., toe pain with capsular

rotation of the DP and medial solear pain with asymmetrical distal displacement of the DP), but also in determining the areas of the ground surface of the foot that can be recruited with techniques such as application of cushion support material to support the digit. The clinician needs to limit the time a foot is elevated for examination to avoid causing further lamellar injury to the opposite foot. Any areas of solear perforation that are present should be assessed to determine whether the disruption is due to a subsolear abscess (common in the chronic laminitis case), perforation of the sole due to severe displacement of the DP, or both; radiographs will also assist with this determination.

Although many veterinarians are resistant to perform nerve blocks on laminitis cases, the author will perform a short-acting nerve block (with lidocaine) in animals too painful to pick up their feet (even under the effects of detomidine analgesia/sedation) in order to decrease their duress during the exam and increase the ease of obtaining radiographs, performing a rapid but thorough examination of the sole, and applying the type of temporary shoeing/padding indicated by the exam and radiographs. In the author's experience, performing the block by anesthetizing the palmar nerves in the mid-cannon region is commonly easier to perform and less stressful to the horse than attempting to block the feet with the more distal nerve blocks. In the very painful horse, nerve blocks decrease the duress for the animal and the time needed to perform necessary procedures, and increase the safety for the caregivers assisting with the animals. The foot not being examined is placed in a commercial padded shoe^a to minimize the trauma to that foot while the other foot is being examined/treated. If the nerve block has not worn off by the time the exam and initial treatment is performed, the horse is restrained from excessive movement until sensation returns to the digit. As nerve blocks will not allow an assessment of solear pain in the feet, it may be best to only block one foot at first so that the other foot can be picked up and the solear surface examined for localization of pain.

After examination of the foot, radiographs should be performed. Whereas the lateral and dorsopalmar views are the critical views in the severe, acute case of laminitis, a solar margin view (60° dorsopalmar oblique view taken with the horse weight bearing on a cassette) is important for assessing the integrity of the DP in the long-standing case. Both front feet are placed on wooden blocks to obtain a lateral and dorsopalmar view, with the radiographic beam centered approximately 1 cm proximal to the ground surface of the foot. The radiographs are critical for 1) determining whether displacement of the DP has occurred, 2) assessing the severity of displacement (and therefore prognosis), 3) detecting signs of chronicity/prior bouts of laminitis, and 4) assessing the type of displacement of the DP (impor-

tant for type of foot care applied to the affected feet).³

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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^aSoft-Ride, Inc., Bacliff, TX 77518.

Endocrine Testing for Pituitary Pars Intermedia Dysfunction (PPID) and Equine Metabolic Syndrome (EMS) Cases

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1. Introduction

Endocrinopathic laminitis is reported to be the most common form of laminitis encountered in equine veterinary practice, and pituitary pars intermedia dysfunction (PPID) and insulin dysregulation (ID)/equine metabolic syndrome (EMS) are frequently complicated by this disease. Practitioners should be aware of diagnostic testing methods for these conditions that are available and clinically useful, as well as how to use them to most strategically manage their patients effectively.

2. Diagnostic Testing for Equine PPID

PPID is a common endocrinopathy of aged horses. Severe or chronic PPID is typically not a diagnostic challenge, given that the diagnosis can often be suggested by clinical signs alone. The presence of hypertrichosis (formerly hirsutism) is considered pathognomonic for PPID, particularly in geriatric horses (>18–20 years of age). In one study, this finding had 71% sensitivity, 95% specificity, 91% positive predictive value, and 84% negative predictive value for diagnosing the disease where a definitive diagnosis was based on postmortem examination findings.¹ The clinical presentation of

PPID in younger horses (or those in early stages of the disease) is more variable, and diagnosis of these cases is more challenging and often relies heavily on the results of diagnostic testing. Tests for laboratory evaluation of PPID cases have evolved over the years; recommended tests have included measurement of resting serum or plasma cortisol, adrenocorticotropic hormone (ACTH), α -melanocyte-stimulating hormone (MSH), glucose, and insulin concentrations, the ACTH stimulation test, the 19-hour (overnight) dexamethasone suppression test (DST), the thyrotropin-releasing hormone (TRH)-stimulation test, and the combined DST/TRH stimulation tests. Other methods that have been evaluated include the domperidone response test, salivary cortisol concentrations, and the urinary corticoid:creatinine ratio. Currently, assessment of endogenous ACTH (eACTH), the TRH stimulation test, and the DST are thought to be the most reliable means of establishing a diagnosis of PPID in a clinical patient, with eACTH and the TRH stimulation are most commonly used clinically. Before testing, it is important to know about the patient's management conditions, diet (including how recently the horse was fed), medication history, and degree of phys-

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ologic stress (as far as it can be known), which could potentially influence test results. Season is another factor that must be considered, given that the secretory activity of the equine pars intermedia varies throughout the year, with highest output noted during the late summer and autumn months in the northern hemisphere (July–November).² Specific tests are described more fully below.

Routine Lab Work

A complete blood count, serum biochemistry evaluation, fibrinogen/serum amyloid A, and urinalysis can be useful to comprehensively evaluate the immune, endocrine, and metabolic status of horses with PPID. Although many horses with PPID have normal bloodwork, abnormalities commonly associated with the condition include anemia, mature neutrophilia, lymphopenia, eosinopenia, hyperglycemia, hypertriglyceridemia (hyperlipemia), increased hepatic enzyme activities, and glucosuria.³ Hyperglycemia is frequently observed in these cases but not consistently enough to be diagnostically useful. The mild-to-moderate hyperglycemia in horses with PPID may be secondary to cortisol-mediated systemic insulin resistance, but many other endocrine factors may also be involved (such as ACTH, α -MSH, leptin, ghrelin, GH, IGF-I). Hypertriglyceridemia may be noted and is reportedly more common in affected ponies than in horses.^{4,5} Severe hypertriglyceridemia accompanying endocrine disease is often associated with insulin resistance in equids but can resolve with appropriate therapy.⁶

eACTH Concentration

Horses with PPID have excessive secretion of pro-opiomelanocortin (POMC)-derived peptides, including ACTH and α -MSH.³ Resting ACTH concentration is a good screening test for diagnosis of PPID, although the clinician should be aware that values may fall within the reference range in early or mild disease. In one study using the DST as the gold standard, resting ACTH concentrations had a sensitivity of 91% in horses and 82% in ponies and a specificity of 100%.⁷ Other publications have reported lower and higher sensitivities and specificities for this test.^{8,9} Similar to cortisol, ACTH concentrations can be increased by stress and blood glucose concentration. Basal [ACTH] >58 pg/mL had a sensitivity of 83% and a specificity of 79% to predict laminitic episodes in ponies in one study.¹⁰

In the northern hemisphere, ACTH concentrations in healthy equids are higher in the late summer and fall than in spring months,² and recently, seasonally adjusted reference ranges have been established for this test. In fall months (July–November), most healthy ponies and horses have ACTH concentrations below 100 pg/mL (~22 pmol/L), whereas in non-fall months (November–July), ACTH concentrations are <35 pg/mL (~7.7 pmol/L).^{2,11} Different cutoff values have been reported

for basal ACTH concentrations depending on the specific immunoassay used, but the current consensus is that for the period of November through July, concentrations >35 pg/mL measured by the immunochemiluminescent assay support a diagnosis of PPID. For the period July through November, an ACTH concentration >100 pg/mL is strongly supportive of PPID, whereas values between 50 and 100 pg/mL are considered suspicious and justify repeat evaluation 3–6 months later. It has been shown that basal ACTH and α -MSH concentrations have better sensitivity and specificity for diagnosis of PPID in the fall when compared with other times of the year, and it has therefore been recommended that testing via these modalities should be ideally performed at this time of the year; however, α -MSH is not currently a commercially available diagnostic test.⁹ Fed state has also been shown to affect baseline and TRH-stimulated ACTH concentrations (fed horses have higher resting and post-TRH ACTH concentrations than non-fed horses); however, no influence of the time of the day at which testing was performed was observed on baseline or stimulated ACTH concentrations.¹² Recommendations for standardization of dietary preparation prior to PPID testing are needed.

To perform this test, blood should be collected in EDTA-containing tubes (preferably plastic), kept chilled on ice prior to transport, or centrifuged and frozen until harvested plasma can be analyzed. When collected in plastic EDTA tubes, equine ACTH is stable for 8 hours in whole blood, and for a longer period of time if plasma is separated and frozen promptly.¹³ Freezing and thawing have minimal effect on ACTH concentrations.¹⁴ ACTH concentration tends to be lower in samples collected in glass tubes, but this difference is minimal¹⁴; overall, equine ACTH is more stable than previously believed. If basal eACTH concentrations are supportive of a diagnosis of PPID, there does not seem to be additional benefit of performing other more complex tests to secure the diagnosis (e.g., TRH stimulation).⁸

TRH-Stimulation Test

The TRH-stimulation test was developed based on the concept that exogenous TRH administration to horses with PPID would result in greater cortisol secretion when compared with unaffected horses.¹⁵ This effect of TRH seems to be due to its ability to increase release of POMC-derived peptides (ACTH and α -MSH) from hyperplastic melanotrophs in the pars intermedia. TRH increases the secretion of α -MSH and ACTH in healthy horses and horses with PPID, but concentrations are greater and more prolonged in horses with PPID.⁸ This effect seems to be more profound for α -MSH than for ACTH in horses with PPID, and α -MSH concentrations seem to remain elevated longer.⁸ In healthy horses, ACTH and α -MSH release following TRH administration exhibits seasonal variation, with higher values measured in summer and fall months compared

with winter months.¹⁶ Importantly, ACTH and cortisol concentrations are dissociated in horses with PPID, and measuring ACTH concentrations after TRH administration seems to be more diagnostically accurate than measuring post-TRH cortisol in differentiating normal horses from those with PPID.¹⁷ For example, in horses with PPID, TRH (1 mg, IV) induced a ~10-fold increase in ACTH concentrations at 4–14 minutes post-administration, whereas in healthy horses, the increase was ~2-fold.^{8,17} The increase in cortisol concentration at 14 and 30 minutes was minimal in both PPID and healthy horses.¹⁷ α -MSH seems to behave similarly when measured post-TRH, but there is no evidence that α -MSH is superior to ACTH if measurements are done within 30 minutes of TRH administration.⁸ There is no commercially available TRH product labeled for this use in horses currently; however, chemical-grade TRH powder can be purchased from a number of companies,^{a,b} diluted in saline solution, filter sterilized, and frozen in 1-mg aliquots until use. Veterinary compounding pharmacies can also prepare TRH as an injectable solution that is reasonably stable at room temperature.^{c18}

To perform the TRH-stimulation test, a baseline blood sample should be collected (plastic EDTA tubes), followed by administration of TRH (1 mg per horse, IV); additional blood samples should be collected at 10 and 30 minutes post-TRH administration, and the baseline and either or both post-TRH samples should be submitted for ACTH concentrations. ACTH concentrations higher than 75 pg/mL (16.5 pmol/L) at 30 minutes post-TRH administration suggest PPID when testing is performed from November through July. If samples are collected at 10 minutes post-TRH, ACTH values can be interpreted as follows: not supportive of PPID if <85 pg/mL and supportive of PPID if >110 pg/mL. Horses with post-TRH ACTH values between 85 and 110 pg/mL 10 minutes post-dosing may be good candidates for repeat testing in 6–8 weeks. If samples are collected at 30 minutes post-TRH, ACTH values greater than 65 pg/mL are supportive of PPID. Importantly, there are no seasonally adjusted reference ranges available for interpretation of this test currently, so the test should not be performed from July to November. Side effects that may be observed in horses after TRH administration include yawning, lip movements, salivation, and trembling.¹⁸ The test does not seem to be significantly affected by fed state, thus dietary preparation is likely not necessary prior to testing.¹⁹ Regarding the TRH stimulation test, the following two strategies should be avoided: 1) concurrent testing for ID via the oral sugar test (OST; as it may confound results), and 2) repeating the TRH-stimulation tests at less than 24-hour intervals.^{18,19}

The TRH stimulation test is becoming the method of choice to diagnose PPID for equine practitioners because it provides reliable results, does not take

much time, evaluates pituitary and adrenal gland function (and can be used to assess thyroid function, if desired), and is not associated with any significant known complications. In addition to sampling at 10 and 30 minutes for ACTH measurements, samples can be collected at 2 and 4 hours to determine T3 and T4 concentrations, allowing evaluation of multiple endocrine axes if clinically indicated.

Endogenous α -MSH

Similar to plasma ACTH, resting α -MSH concentrations follow a similar secretion pattern in healthy and PPID-affected horses throughout the year.¹⁶ Resting α -MSH concentration has the potential to become a routine diagnostic test for PPID; however, commercial assays are not readily available currently and at this point, it is often expensive to measure. Currently, α -MSH concentrations in horses are only determined for research purposes. It is recommended to collect blood samples in EDTA-containing tubes. Normal seasonal values for plasma α -MSH in healthy and PPID horses have been published.^{8,20} Reported sensitivities and specificities for resting α -MSH concentrations ≥ 30 pmol/L and α -MSH >50 pmol/L were 68% and 93%, 63% and 93%, respectively.⁸ In the same group of horses, 30 minutes after TRH stimulation, sensitivities and specificities were 93% and 87% for α -MSH ≥ 30 pmol/L, and 81% and 93% for α -MSH >50 pmol/L.⁸ Based on these results, using the α -MSH response to TRH stimulation does not confer major diagnostic advantage over baseline α -MSH values; this is different to the ACTH response to TRH, which has improved diagnostic value over baseline ACTH concentrations.

DST

The DST has historically been the most widely used method in the diagnosis of equine PPID.³ The rationale behind this test is that, in PPID-affected horses and ponies, ACTH and cortisol secretion are not suppressed by exogenously administered corticosteroid (dexamethasone) because ACTH in these animals is primarily produced by melanotrophs of the pars intermedia; these cells (which are hyperplastic and display more active secretion in PPID) are not sensitive to negative feedback by glucocorticoids, which in this setting is diagnostically useful. In healthy equids, ACTH is primarily secreted by the corticotrophs of the pars distalis, which are subject to negative feedback by glucocorticoids.

To perform a 19-hour DST, a baseline serum sample should be collected (between 4–6 pm), followed by administration of dexamethasone (40 μ g/kg, IM). A second serum sample should be collected 19 hours later (~12:00 pm). In horses with intact negative feedback sensitivity, it is expected that serum cortisol concentrations will be below 1 μ g/dL (27.6 nmol/L) 19 hours post-dexamethasone administration, whereas horses with PPID will have minimal

cortisol suppression. This test is simple, inexpensive, and continues to be performed frequently by equine practitioners; however, seasonally adjusted reference ranges for interpretation are not available for this test, and false-positive tests may occur if animals are tested in autumn. This test should not be performed between the months of July and November in the northern hemisphere for this reason.

Clinicians should be aware that false-positive and false-negative results occur with the DST. False positives (20–40%) are common when testing is done in the fall (as with the TRH stimulation test, there are no seasonally adjusted reference ranges against which to interpret the DST currently), whereas false negatives may occur early in the disease process. For horses with clinical evidence of PPID and a non-diagnostic DST, it is recommended to repeat testing 4–6 months later, or consider other tests. With regard to the risk of laminitis associated with corticosteroid administration, whereas an association between short-acting glucocorticoids and laminitis has been suggested, no controlled study has quantified this risk well. When performed in 66 horses with evidence of PPID, the DST did not induce or worsen any signs of laminitis.²¹ Despite the lack of objective information (including lack of an experimental model for induction of corticosteroid-associated laminitis), disclosure of risk to clients (however small) is important prior to performing the test. If a veterinarian or client is worried about complications associated with the DST, other methods (e.g., eACTH concentration, TRH-stimulation test) are available. The DST is gradually being supplanted by these other methods that are more time efficient and accurate in achieving a diagnosis of PPID.

Other diagnostic tests (such as a combined DST/TRH-stimulation test, baseline cortisol concentrations, the ACTH stimulation test, urinary corticoid:creatinine ratios, basal insulin and glucose concentrations, and the domperidone stimulation test) have been developed and evaluated for their utility in clinical diagnosis of equine PPID; however, none have been shown to have superior performance to the eACTH, TRH stimulation, or the DST and thus are not currently recommended.

3. Diagnostic Testing for EMS

Equine metabolic syndrome is among the most common endocrine disorders of adult horses and is currently defined as overweight/obese body condition, clinicopathologic evidence of ID, and laminitis (historical or current). Diagnostic testing for the syndrome is primarily related to identification of abnormalities in insulin and glucose dynamics, which will be the focus of the following discussion.

Adiposity and Body-Condition Scoring

Obesity is detected upon physical examination of the horse and determining a body condition score (BCS;

1–9).²² Regional adiposity is commonly detected in insulin resistant (IR) horses, and mean neck circumference has been negatively correlated with insulin sensitivity in obese horses with IR.²³ Neck circumference can be measured with a tape measure. These measurements are made by dividing the distance along a line from the poll to the cranial aspect of the withers (x) by four and measuring the circumference of the neck at three equidistant points (0.25x, 0.50x, and 0.75x). Expansion of the adipose tissue within the neck is commonly referred to as a “cresty neck” and, with the exception of stallions, this finding is suggestive of IR in horses.²³

Enlarged fat deposits may also be found close to the tail head or appear as randomly distributed subcutaneous swellings. Geldings are sometimes presented for evaluation of preputial swelling, and mares may show enlargement of the mammary glands. Both of these problems are related to adipose tissue accumulation, which can also interfere with lymphatic return in these regions. Affected horses can develop edema in these areas as well when they are left standing in their stall for too long, and this problem typically improves with exercise. Supraorbital fat accumulation is also a frequent finding. EMS is sometimes recognized when horses develop other medical problems, including colic, hyperlipemia, and reproductive dysfunction. Obesity has also been associated with abnormal reproductive cycling in mares, although fertility seems to be relatively unaffected for the most part.²⁴

Regional adiposity/obesity is a diagnostic criterion for EMS, but it must be recognized that fat redistribution is also seen in older horses with PPID.³ It is therefore necessary to examine the patient for clinical signs of PPID, including delayed hair coat shedding, hypertrichosis, hyperhidrosis, skeletal muscle atrophy, polyuria, polydipsia, and/or recurrent pyogenic infections. Importantly, not all horses with insulin resistance/ID are obese or overweight.

Laminitis and EMS

Horses with EMS commonly suffer from laminitis, which is recognized when lameness is detected, hoof testers are applied to the feet, or pedal radiographs are performed. Divergent growth rings indicating abnormal hoof growth can be observed in horses with or without a documented clinical history of laminitis. Some horses are not lame upon physical examination but have radiographic evidence of third phalanx rotation or distal displacement. Laminitis often first develops after the horse has been grazing on pasture grass that is rich in nonstructural carbohydrates. This happens at times of the year when grass is abundant and growing rapidly or when responding to cooler temperatures in the fall. Owners of horses with recurrent laminitis also report that laminitis episodes occur after changes in season or with the onset of cold weather.

Assessment of Insulin and Glucose Dynamics

Specific blood screening and dynamic tests based on glucose and insulin concentrations must be performed for an accurate diagnosis of IR. Screening tests include fasting glucose and insulin concentrations. However, it is now recognized that many affected animals that exhibit abnormally high insulin responses to dynamic challenge tests (see below) have normal resting-insulin concentrations.²⁵ Horses should not be provided feedstuffs rich in nonstructural carbohydrates within 6–8 hours of testing to accurately interpret the results²⁶ (although there is debate currently about the proper dietary preparation for testing).²⁷ One suggested method for preparation recommends that the horse is fed one flake of hay overnight (after 10:00 pm), with blood collected in the morning (ideally between 7:00 and 10:00 am). Blood samples must be refrigerated and sent for analysis to a reputable laboratory running an assay validated for horses for analysis. Horses are considered to have IR if fasting glucose concentrations >110 mg/dL (6.1 mmol/L) and insulin concentrations >20 μ IU/mL. In one study from our group, evaluation of basal serum insulin concentration was normal (<20 μ IU/mL) in 12/12 horses; however, according to frequently sampled insulin-modified intravenous glucose tolerance test (FSIGTT) with Minimal Model analysis, seven of these horses were actually IR.²⁵ Based on these results, basal insulin concentration, although specific, has insufficient sensitivity to be used as a single screening test for IR in equids. It should also be noted that within an individual animal, there can be marked inter-day variation in serum insulin concentrations; this is another major limitation in the use of resting insulin for diagnosis of IR.

Proxy estimates of insulin sensitivity from single measurements of glucose and insulin have been used for diagnosis of IR.²⁸ Commonly used proxies have included the glucose-to-insulin ratio, the reciprocal of the square root of insulin (insulin-0.5), the quantitative insulin sensitivity check index ($1/(\log[\text{insulin}] + \log[\text{glucose}])$), and the modified insulin-to-glucose ratio ($800 - 0.3 \times [\text{insulin} - 50] / 2 / [\text{glucose} - 30]$; this test is an estimate of pancreatic β -cell responsiveness). These proxy measurements have been suggested to be useful for distinguishing groups of laminitis-prone and control ponies, but they did not accurately predict predisposition to laminitis in individual ponies.²⁹ Seasonal variation in the proxy measurements of insulin sensitivity also have been observed, confounding interpretation.

When results of resting basal insulin concentrations are inconsistent or when insulin is <20 μ IU/mL in the face of other clinical or historical findings indicative of EMS, dynamic evaluation of insulin sensitivity and/or glucose tolerance is recommended. These tests are also useful to assess severity of IR, to monitor disease progression, and

to evaluate response to treatment. Dynamic tests include the intravenous glucose tolerance test (IVGTT), the combined glucose-insulin test (CGIT), and the oral glucose tolerance test (OGTT)/OST, among others. Methods for quantitative assessment of insulin sensitivity such as the euglycemic hyperinsulinemic clamp and Minimal Model analysis of a FSIGTT provide valuable information in the research setting, but these tests are impractical for clinical use.

The IVGTT has historically been one of the most frequently used methods for assessment of glucose tolerance in the horse. It requires dextrose administration and sequential blood sampling to measure blood glucose concentrations, which can be done at the stall side/on-farm using a handheld glucometer. Horses should be held off feed for 6–8 hours prior to testing. Dextrose (150–300 mg/kg body weight [BW]; 50% solution) is administered IV after collection of a baseline blood sample. Additional blood samples are collected every 30 minutes for 180 minutes. In insulin-sensitive horses, glucose concentrations should be back to baseline values by 150 minutes post-dextrose administration. Horses with elevated glucose at 180 minutes are likely to have IR. This test can be simplified for field use by collecting samples at 0, 150, and 180 minutes.

The goal with the CGIT is to assess insulin sensitivity by determining the time when glucose concentrations return to baseline values after the combined IV administration of dextrose and insulin as boluses. An IV catheter is placed the day before or just prior to testing. The horse is fasted or offered one flake of hay overnight. After collection of a baseline blood sample, dextrose (150 mg/kg BW IV; 50% solution) is administered and immediately followed by injection of regular human insulin (0.1 IU/kg BW, IV). Blood samples are collected at 0, 1, 5, 15, 25, 35, 45, 60, 75, 90, 105, 120, 135, and 150 minutes post-administration to measure glucose concentrations. Insulin concentration can be measured in a sample collected 45 minutes post-administration. A horse is considered to have IR if the blood glucose concentration is above baseline or insulin concentration is >100 μ IU/mL at 45 minutes post-administration. This test can be performed in the field, and glucose concentrations can be measured with a handheld glucometer. It is important to keep in mind when performing the CGIT that hypoglycemia can be a potential complication, and having dextrose readily available for rescue purposes is highly recommended. A more practical and economical modification of this test protocol is to collect a baseline blood sample, administer dextrose immediately followed by insulin, and measure glucose and insulin concentrations at 45 minutes post-drug administration. Interpretation is as previously described.

A modified approach to the OGTT, the OST, has recently been recommended as the preferred method for dynamic assessment of glucose and insulin dy-

namics in horses in clinical settings. This test involves the oral administration of corn syrup (Karo Light at a dosage of 15 mL per 100 kg body weight, equivalent to 150 mg sugar/kg BW) after a short period (8–10 hours) of feed withholding. A blood sample is collected at 60 and 90 minutes after sugar administration for measurement of glucose and insulin concentrations. An insulin concentration $>60 \mu\text{IU/mL}$ at either time point suggests abnormal hyperinsulinemia. An excessive glucose response is indicated by a glucose concentration $>125 \text{ mg/dL}$ ($>6.9 \text{ mmol/L}$) at 60 or 90 minutes. An “in-feed OGTT” has also been used to assess glucose and insulin responses in EMS suspects, particularly in areas where corn syrup is difficult to obtain.³⁰ For this test, the animal is provided a small meal composed of dextrose powder (1 g/kg bodyweight) mixed with a small amount (~1 lb or 450 g) of a low-glycemic feedstuff, such as hay chaff. A blood sample for measurement of insulin concentration is collected 2 hours after feeding; values at $>85 \mu\text{IU/mL}$ are considered to be abnormal. For both the OST and in-feed OGTT, owners may be concerned about adverse effects associated with the administration of sugar/glucose to insulin-resistant animals (e.g., laminitis), but the risk seems to be very small based upon the author’s experience. In addition, investigators who have administered hundreds of OSTs to horses and ponies for epidemiologic and genetic studies of EMS have reported no new laminitic episodes immediately post-testing; the risk seems to be quite low.

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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.

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^aTRH, Sigma-Aldrich Co, St. Louis, MO 63103.

^bTRH, Phoenix Pharmaceutical, Burlingame, CA 94010.

^cProtirelin (TRH), Wedgewood Pharmacy, Swedesboro, NJ 08085.

Sepsis-Related Laminitis: Prevention in the Horse at Risk and Treatment of the Ongoing Case

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1. Introduction

Laminitis is a relatively common consequence of diseases characterized by the systemic inflammatory response syndrome, particularly if this inflammation is triggered by bacterial infection or bacterial products including endotoxin ("sepsis"). Although the presence of clinical signs (tachycardia, fever, hyperemic mucus membranes) and clinical laboratory evidence (neutropenia and toxic neutrophils) of sepsis/endotoxemia have long been recognized as a risk factor for the development of laminitis, it was only recently that this relationship was confirmed in a clinical retrospective study.¹ Success in treating horses with diseases such as colitis, metritis, and pneumonia is still limited by our ability to prevent acute laminitis: if laminitis develops in these cases, it often involves rapid progression of the lesion and mechanical failure of the lamellae, with euthanasia or long-term debilitation due to chronic laminitis being common outcomes. Advances in the way we manage these primary diseases and concurrent sepsis, as well as the incorporation of specific preventative strategies for laminitis, are leading to improved outcomes for horses with acute septic disease.

2. Pathophysiology of Sepsis-Related Laminitis

Sepsis is differentiated from simple infection by the presence of an aberrant or dysregulated host re-

sponse (inflammatory, coagulopathic, and metabolic derangements) and organ dysfunction.² In most species including humans, the development of end-organ dysfunction/failure ("multiple organ dysfunction syndrome" [MODS]), most commonly affecting the lungs, liver, and kidneys, has a major effect on survival in cases of sepsis. Laminitis seems to be a form of end-organ dysfunction/failure that is ultimately most important in terms of recovery for the adult horse with sepsis. The pathophysiology of organ dysfunction in sepsis (and sepsis-associated laminitis) is still poorly understood. Efforts to determine the mechanisms that lead to sepsis-associated laminitis have mirrored those in human MODS research, with the investigation of circulatory derangements, local inflammatory processes, apoptosis, and nonischemic derangement of cellular energy metabolism receiving the most attention. Although there is some evidence of microvascular dysfunction in MODS and laminitis, there is no evidence of true ischemia. The central role of inflammation in the pathogenesis of acute laminitis has been highlighted experimentally, with endothelial activation, cytokine and chemokine up-regulation, and leukocyte emigration into the lamellar tissue occurring early during the development of experimentally induced laminitis. There is little evidence that apoptosis or

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oxidative damage play a primary role in laminitis development. Since the lamellae have a unique mechanical role, the lamellar basal epithelial cell adhesions and the integrity of the extracellular matrix have received special research attention. Recent evidence suggests that enzymatic degradation of extracellular matrix components by e.g., matrix metalloproteinase enzymes seem to play only a secondary role. There is evidence of nonischemic energy failure (mitochondrial dysfunction) in models of human sepsis that is thought to play a role in MODS.³ This process may represent a down-regulation of cellular metabolic pathways that is actually protective in tissues during sepsis and new evidence suggests that mitochondrial responses to sepsis are tissue specific.⁴ Similar disruption of energy metabolism in sepsis-induced laminitis has not been documented in studies thus far⁵; however, if present, this could interfere with the maintenance of cellular adhesions and contribute to this lesion. Although insulin dysregulation may be a feature of sepsis in horses, it is clear from experimental sepsis-related laminitis models using carbohydrate overload⁶⁻⁸ that laminitis develops in the absence of clinically significant hyperinsulinemia. Unfortunately, the pathway from the systemic inflammation of sepsis in horses to lamellar structural failure remains unclear.

3. Strategies for Prevention of Sepsis-Related Laminitis

Once established, laminitis causes derangements of the lamellar structure that are largely irreversible; therefore, efforts should be aimed at prevention and this begins with identification of the at-risk horse. Conditions associated with a high risk of laminitis development include colitis, enteritis, complicated gastrointestinal obstructions, metritis, pneumonia, and alimentary carbohydrate overload.^{1,9-13} Therapeutic efforts to control the primary disease and the systemic inflammation in cases of equine sepsis are paramount. Intravenous fluids for circulatory support, binding of circulating endotoxin using polymixin B and hyperimmune plasma, and the use of NSAIDs to control downstream inflammation are reasonable treatment strategies, particularly in cases of gut-derived sepsis.¹³ Although one study seemed to identify a possible protective effect of low-molecular-weight heparin in surgical colic cases, the control group was historical and the evidence weak.¹⁴ Treatment with unfractionated heparin failed to have an effect on the development of sepsis-related laminitis induced experimentally with carbohydrate overload.¹⁵

4. Digital Hypothermia (Cryotherapy)

The protective effect of prophylactic continuous cooling of the feet has been demonstrated in several experimental studies¹⁶⁻¹⁹ and it remains the only therapy to repeatedly withstand scientific rigor. Supporting its clinical application, a recent retro-

spective study of hospitalized equine colitis cases showed that survival was 98% in horses that did not develop laminitis, compared with only 48% in those that did, and that horses treated with digital hypothermia were 10 times less likely to develop laminitis.²⁰ There are several potential mechanisms by which hypothermia might protect against sepsis-related laminitis. When applied before the onset of clinical lameness in an experimental model, continuous digital hypothermia dramatically inhibited transcription of inflammatory mediators including cytokines, chemokines, and cyclooxygenase in lamellar tissue.¹⁷ In addition, hypothermia had an inhibitory effect on lamellar-matrix metalloproteinase expression,¹⁹ a finding consistent with experimental studies of hypothermia in brain trauma²¹ and cardiac arrest.²² Interestingly, despite a marked therapeutic effect in preventing lesion progression when applied after the onset of lameness in an experimental laminitis model, inhibition of inflammation did not seem to be a therapeutic mechanism based on the lack of a detectable effect on inflammatory mediator expression.²³ In other animal models of sepsis, preservation of cellular energy metabolism and mitochondrial function,^{24,25} reduced inflammation²⁶⁻²⁹ and inhibition of apoptotic pathways³⁰ are effects of hypothermia that protect against end-organ damage in the liver, lung, and heart. The contribution of cellular energy failure (nonischemic) to the different forms of laminitis is unclear,⁵ but hypothermia of the equine digit may exert protective effects on lamellar tissue by modulating mitochondrial function and reducing metabolic demands.

Any horse that is at immediate risk of developing acute laminitis is an appropriate candidate for the application of continuous distal-limb hypothermia. Although prophylactic application is ideal, there is experimental evidence supporting digital hypothermia application in horses with acute sepsis-related laminitis (i.e., with pre-existing lameness).¹⁸ There is currently no scientific evidence to guide the duration of therapeutic hypothermia nor the temperature specifically in the clinical setting; however, continuous cooling of all four feet until after the abatement of clinical signs/clinical laboratory evidence of sepsis is generally recommended, which may be several days in some cases. Based on experimental data, digital hypothermia should be aimed at achieving hoof wall surface temperatures that are (at least) consistently below 10°C, and it seems that cooling from the mid-cannon region distally (including the hoof and sole) is required to effectively cool incoming arterial blood as well as prevent heat transfer from the environment to the lamellae via the hoof itself. A water interface against the limb overcomes the conduction barrier of the hair coat and negates the difficulty in getting consistent contact of a heat exchanger with the uneven surface of the equine distal limb.³¹ Immersion of the limb from the mid-upper metacarpus/metatarsus distally in an ice-and-water mixture effectively achieves this, although constant ice re-

plenishment is labor intensive. A practical and effective solution particularly for field application is still lacking.

There are anecdotal reports of complications in horses being treated with digital hypothermia: dermatitis of the pastern and maceration of the coronary band can occur particularly when cooling for more than 5 days, but in most cases this resolves with no or minimal treatment once the cooling is ceased. On rare occasions, more extensive and severe necrosis of superficial distal limb tissue that is consistent with true frostbite is reported—this seems to be more commonly associated with the application of ice typically directly from a freezer (between -20°C and -30°C) directly to the limb without a water interface, which should be avoided.

5. Treatment of the Acute Case

There is experimental evidence that the application of digital hypothermia during the acute phase of sepsis-related laminitis (after lameness develops) can help to limit progression.¹⁸ Although there is no evidence to guide the duration of therapeutic cooling in acute laminitis cases, the therapeutic effect is likely to diminish past seven days after the onset of lameness, particularly if the sepsis has resolved. The analgesic effects of digital hypothermia can also be useful in acute cases in conjunction with traditional pharmacological analgesia (including NSAIDs).

Restricting ambulation is paramount in the early stages of acute laminitis regardless of the cause. Horses should be confined to a stall and encouraged to lie down by providing deep comfortable bedding. Tranquilizers and sedatives may encourage recumbency and reduce voluntary weight bearing and ambulation in horses with acute laminitis. Providing support to the caudal sole and frog using either orthotic support material attached to the feet (silicone impression material, foam, or similar) and/or bedding material that conforms to the foot and yields both under the toe to minimize break over and also while pivoting (ideally sand) can help to reduce mechanical distractive forces on the lamellae and often rapidly improves lameness in acute cases. Careful serial radiographic assessment is essential to track progress in the early stages of acute laminitis.

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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.

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Endocrinopathic Laminitis: Nutritional Management and Pharmacotherapeutics in Clinical Patients

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1. Introduction

Endocrinopathic laminitis is the most common form of laminitis encountered by the veterinarian in equine practice and is often associated with obesity and insulin dysregulation (ID). Consequently, nutritional, exercise, and (if necessary) pharmacologic interventions are mainstays of clinical patient management. This paper describes some strategies and guidelines that can be used by veterinarians when devising nutrition and medication plans for endocrinopathic laminitis patients.

2. Nutritional Management

Nutritional management of equine metabolic syndrome (EMS) and equine ID (which may also accompany equine pituitary pars intermedia dysfunction [PPID]) currently involves three approaches: 1) reducing the nonstructural carbohydrate (NSC) content of all feedstuffs provided to the animal, 2) restricting pasture access until ID has been shown to improve via follow up laboratory assessments (with cautious and gradual re-introduction to pasture after that point), and 3) caloric restriction to encourage weight loss if a reduction in body condition is indicated. The first approach involves selec-

tion of forage with a low sugar/starch/fructan NSC content, which can be determined by submitting a forage sample for nutritional analysis. Taking several samples of several bales in a purchased lot of hay is recommended, given that single samples can be misleading; use of a hay core sampler is recommended. The NSC content of tested forage can be calculated by adding the measured starch and ethanol-soluble carbohydrate fractions together, and this number should ideally fall below 10% on a dry-matter basis as-fed (in all dietary components, not just the forage). The amount of NSC intake that can be tolerated by an individual EMS patient depends on their degree of ID. Horses with severe ID (resting insulin concentration > 75–100 μ IU/mL, abnormal oral sugar test, or combined glucose/insulin test results, actively laminitic) should be maintained on a strict diet with a NSC content < 10%, whereas mildly affected animals or animals that are improving with treatment can likely be fed hay with higher NSC content (gradually introduced). If hay has an NSC level > 10% and must be used (i.e., the client has already purchased a significant amount of it), soaking the hay in cold water for 3–6 hours prior to feeding should lower the sugar content by ~20%.¹

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Soaked hay should be fed and consumed promptly, given that it can support mold growth readily; the soaking liquid should be discarded in a place where the horse cannot access it, given that it can be very palatable to some horses.

Lean horses with insulin resistance (IR)/ID (such as an animal genetically at risk for EMS that has never been allowed to become overweight, or an EMS patient that has lost weight but remains IR) can be challenging to feed, given that they often require more calories, which must be offered in a way that does not exacerbate ID. This can be accomplished by feeding one of the low-sugar/low-starch (low-NSC) pelleted feeds that are currently commercially available, although determining the product's NSC content is recommended prior to feeding (this information will not be included on the feed tag). These feeds vary in their NSC content, so the severity of ID must be taken into account before one is selected. It is also better to divide the daily ration into multiple small meals and to feed hay beforehand to slow rate of consumption and gastric emptying. These strategies are employed to lower the glycemic response to a meal, which is the degree to which blood glucose concentrations (and consequently, blood insulin concentrations) increase in response to feeding. Individual horses may respond differently to the same product, so it is advisable to recheck glucose and insulin concentrations 7–14 days after introducing a new diet. Horses with severe ID can be particularly difficult to manage and may require a more individualized approach to diet formulation; getting an equine nutritionist involved in the case can be very helpful. Molasses-free beet pulp can be fed as a more economical alternative to commercial feeds. This is a feedstuff with a low glycemic index and provides calories through hindgut fermentation and volatile fatty acid production. Fat and fiber are safer sources of calories than NSC for horses with ID that need to maintain or gain weight.²

Weight loss should be encouraged in overweight or obese horses by decreasing the total number of daily calories consumed. In horses that are overweight and being overfed (which is often the case), removing all concentrate feed(s) from the diet is often a sufficient change to allow the horse to achieve its ideal body weight within 8–12 weeks. Total caloric intake should initially be met by feeding hay (ideally a grass hay tested and determined < 10% NSC) in amounts equivalent to 1.5–2.0% of *current* body weight. If the horse does not lose weight as expected over 6–8 weeks, the amount fed should be gradually decreased over several weeks to 1.0–1.5% of *ideal* body weight; feeding less than 1.0% of ideal body weight in forage per day is not recommended, given that this may represent a risk for hyperlipidemia/hyperlipemia in overweight equids with ID.

These strategies are effective for horses kept in stalls or dirt lots, but weight loss is more difficult to achieve when horses have access to pasture (given

that this represents a dietary component whose consumption is difficult to quantify or control effectively). Strategies for limiting grass consumption on pasture include restricted (30–60 minutes) turnout periods; confinement to a small paddock, round pen, or area enclosed with electric tape/braid fence; or use of a grazing muzzle. Appropriate vitamin and mineral supplements should be provided to horses confined to dirt paddocks or stalls or whose daily forage ration consists of a restricted amount of grass hay; protein (30–35%) and trace mineral/vitamin products are commercially available^{a,b}, and in the author's experience, 0.5–1.5 lb per day of one of these products is typically sufficient for a 450–500 kg animal whose diet is otherwise grass hay only (label recommendations should be consulted before use of an individual product). Pasture access must remain restricted until insulin sensitivity has improved (ideally as documented with follow up laboratory testing), given that carbohydrates consumed on pasture can trigger recurrent bouts of laminitis in susceptible horses. Pasture is also an unregulated source of starch, sugars, and fructans, so these carbohydrates can continue to exacerbate ID, even when other aspects of the diet have been controlled.

Horses with recurrent laminitis may require housing away from pasture indefinitely. These animals should be housed in dirt lots so that they are able to move freely and exercise once laminitic pain has been controlled. Mildly affected horses can be returned to pasture if ID can be managed, but caution should be exercised when grass is going through dynamic phases, such as rapid growth in the spring or senescence in the fall. Based on the diurnal variability of NSC content in pasture grass, early morning grazing (i.e., before sunlight becomes intense) is likely the safest time to offer limited periods of grazing for horses with ID.³

3. Pharmacotherapeutics for EMS

The majority of EMS patients can be effectively managed by lowering the NSC content of the diet, reducing body weight if the animal is overweight or obese, instituting a regular exercise program, and controlling access to pasture. In fact, there is recent published evidence of the effectiveness of diet and exercise programs that are tailored to the individual horse or pony in improving insulin and glucose dynamics and enhancing weight loss.⁴ However, it takes time for these management changes to take effect, so pharmacological interventions can be considered to accelerate progress if the patient has recurrent or intractable bouts of laminitis (particularly as it restricts their ability to perform regular exercise). Levothyroxine sodium can be administered to accelerate weight loss and improve insulin sensitivity in obese horses but should be avoided in lean EMS patients because of the reduction in body weight that may accompany its use. Metformin may also be useful; this drug may improve insulin

sensitivity in horses and ponies with ID without affecting body weight significantly.

Levothyroxine Sodium

Insulin and glucose dynamics can be improved and weight loss can be encouraged in overweight/obese EMS patients when levothyroxine sodium is administered orally at a dosage of 48 mg (total per 500-kg horse)/day for 3–6 months.⁵ Smaller equids (ponies, American Miniature Horses) can be given 24 mg levothyroxine sodium per day for the same time period. Levothyroxine sodium^c is one available product that has been used extensively in the treatment of horses with EMS; one scoop of powder provides 12 mg levothyroxine sodium, so 4 tsp should be administered in the feed or by mouth once daily for a light breed horse receiving treatment. Other products are available on the market and may be equally suitable for this use; most of the author's clinical experience has been with levothyroxine sodium^c. When levothyroxine treatment is discontinued, horses should be weaned off the drug by halving the dose for 2 weeks, and then halving it again for 2 more weeks. The risks and benefits of treating horses with levothyroxine at lower dosages for longer periods have not been evaluated, but conventional doses for 9–12 months do not seem to induce significant deleterious cardiovascular effects.⁶

Measured serum total thyroxine (tT4) concentrations will be elevated during levothyroxine therapy; however, serum concentrations vary considerably within and between horses. Serum tT4 concentrations often range between 40 and 100 ng/mL in treated horses, indicating that levothyroxine sodium is being given at supraphysiological doses. However, clinical signs of hyperthyroidism, such as sweating or tachycardia, have not been reported in treated horses. Horses undergoing treatment with levothyroxine should receive some degree of dietary restriction, given that this medication has been subjectively observed to increase feed intake during treatment. Weight loss is unlikely to efficiently occur if the horse is given ad libitum access to feedstuffs (particularly pasture).

Metformin

Metformin, a functional agonist of the highly conserved enzyme adenosine-5'-monophosphate-activated protein kinase (AMPK), is an orally bioavailable biguanide medication that has been used extensively as an antihyperglycemic and insulin-sensitizing drug in the clinical management of human metabolic syndrome and type II diabetes mellitus. The pharmacokinetics and pharmacodynamics of this drug have been well characterized in humans (in fact, it is one of the most heavily prescribed medications in the United States); however, whereas metformin has been used empirically to treat equids afflicted with EMS (and while some preliminary pharmacokinetic studies have been published), peer-reviewed pharmacodynamic infor-

mation regarding metformin's effects in equids is scarce. When the effects of metformin on insulin sensitivity were assessed in horses and ponies with ID, a positive response was detected initially without the development of hypoglycemia; however, long-term results were variable (metformin was also not the only treatment provided for the animals in this study).⁷ Metformin was administered at a dosage of 15 mg/kg orally twice daily in the aforementioned study, but the pharmacokinetics of this drug has been subsequently examined, and results suggest that the drug has poor oral bioavailability in horses and should likely be given at an increased dose when compared with that recommended for human use (30 mg/kg instead of 15 mg/kg) q 8–12 h before a meal.⁸ More recent work suggests that metformin may attenuate postprandial hyperglycemia when given prior to administration of an enteral carbohydrate challenge in horses⁹; the drug may therefore have some utility in mitigating the risk of pasture in EMS-affected horses after dose and frequency recommendations have been optimized. Additional studies are required to assess the safety and efficacy of this treatment for EMS, but the drug could potentially affect several attractive therapeutic targets in this condition. In fact, metformin has been shown to enhance polarity and adhesiveness of epithelial cells in other species and experimental systems, and evaluation of the drug for use in the prevention of endocrinopathic laminitis based on this characteristic, as well as its effects on insulin and glucose dynamics, is certainly warranted. AMPK activity within the digital laminae of ponies subjected to high-carbohydrate feeding has been shown to be decreased¹⁰, so it is possible that administration of an AMPK agonist like metformin in this setting may be helpful. No adverse effects of metformin administration have been reported in treated equids to date, but these may not be apparent until use of the drug is more widespread in this species. Metabolic acidosis (sometimes severe and life threatening) has been reported in people treated with metformin, and the risk of this complication seems to be increased in patients with underlying renal disease; while this has not been reported in horses to date, assessing bloodwork with attention to renal values in equine patients prior to initiating therapy with metformin may be warranted.

Numerous other treatments have been suggested for the management of ID in horses, including thiazolidinediones (such as pioglitazone and rosiglitazone, all functional PPAR γ agonists),^{11–13} magnesium supplementation, chromium, clenbuterol, cinnamon, curcumin, etc. Each of these therapies may be of some benefit (particularly in combination), but additional studies are required to establish their efficacy. Preliminary work suggests that at least one commercially available nutritional supplement had no detectable effect on the degree of ID in treated horses.¹⁴

4. Pharmacotherapeutics for PPID

Treatment of horses with PPID involves administration of medication to suppress secretory activity of the pars intermedia and management changes,¹⁵ and a labeled, US Food and Drug Administration–approved preparation of the dopaminergic agonist pergolide mesylate^d is available and recommended as the first-line treatment of PPID. Most horses receive a starting pergolide dose of 1 mg/day, but initiating treatment at 0.5 mg/day may be helpful for mitigating inappetance and loose manure that can accompany the first few days of treatment. The dose can be increased to 1 mg/day after 2–3 weeks. Monitoring plasma adrenocorticotropic hormone (ACTH) concentrations in response to therapy (4–6 weeks after a dose alteration) can be helpful for optimization of dosing, and cyproheptadine (0.3 mg/kg PO q 12 h) can be added as an adjunctive therapy in horses whose clinical signs persist despite pergolide dose escalation (or if pergolide dose escalation becomes financially untenable). Empiric pergolide treatment of horses with newly diagnosed laminitis of unclear etiology is a common practice, particularly if the horse is geriatric. Nutritional management strategies employed for horses with EMS (i.e., those indicated for management of ID/IR) are also often appropriate for horses with PPID; In addition, geriatric horses with PPID with poor dentition may require further dietary modification to address this concern (chopped or pelleted forages or complete feeds may need to be the primary source of calories if they cannot masticate hay properly).

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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.

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^aEnrich Plus, Purina, St. Louis, MO 63166-6812.

^bGro'N Win, Buckeye Nutrition, Dalton, OH 44618.

^cThyro-L, Lloyd, Inc., Shenandoah, IA 51601.

^dPrascend, Boehringer Ingelheim Vetmedica, Inc., St. Joseph, MO 64506-2002.

Supporting Limb Laminitis in Clinical Practice

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1. Introduction

Despite significant recent advances in our ability to treat complicated fractures and other painful limb conditions in horses, supporting-limb laminitis (SLL) remains a primary limiting factor to treatment success in these cases. Although the severity and duration of lameness are considered risk factors, the development of SLL is still unpredictable, both in terms of timing and also with respect to which cases will succumb to it (and what degree of pain in the limb with the primary condition is necessary for SLL development). This form of laminitis tends to be commonly associated with rapid and severe failure of the lamellae, with subsequent distal displacement ("sinking") of the distal phalanx within the hoof capsule. The incidence has been estimated at approximately 10% to 15% of horses that present for painful limb problems (or require limb casts) in North American studies¹⁻⁴; however, the threat of SLL contributes to a reduced propensity to even attempt treatment in many complicated painful limb conditions (particularly complicated fractures), with many of these horses instead being euthanized.

2. Pathophysiology

Mechanical and vascular mechanisms have been considered by authors as potential contributors to the pathophysiology of SLL, but there is very little

published evidence.^{2,5} It is well accepted that, in the standing horse, the body mass is divided between the fore and hind limbs in a 60:40 ratio.⁶ With peak ground reaction forces increasing to be equivalent to 0.25 times body weight (bwt) at the walk, 0.5 times bwt at the trot, and up to 3 times bwt at the gallop, it seems unlikely from a mechanical perspective that compensatory load redistribution in the standing horse bearing weight on a single limb could exceed the mechanical tensile strength of the lamellae. However, the ability of consistent increases in load to trigger lamellar epidermal remodelling cannot be discounted, and evidence that lamellar remodelling may occur in response to stress⁷⁻⁹ has important implications for the pathophysiology of SLL. The lamellar tissue has a high requirement for glucose, presumably for maintaining the integrity of cellular attachments, yet there is no means for local glycogen storage. Therefore, reduced (or inadequate) supply of blood glucose may rapidly lead to energy failure. Almost 30 years ago, it was first demonstrated that there was a valve-like mechanism in the digital arteries of the loaded limb leading to a cut-off of arterial blood supply during the loading phase.^{10,11} This work has been repeated recently by the author's group using three-dimensional computed tomography studies, demonstrating arterial attenuation and occlusion under load in cadaver limbs that affects contrast fill in the arterial

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vasculature within the hoof capsule.⁵ Recent studies utilizing microdialysis, (a technique that allows real-time detection of local energy metabolites and blood flow in the lamellar interstitium) showed that lamellar perfusion and energy balance are largely determined by the frequency of limb-load cycling (weight-shifting frequency), which seems to override other manipulations such as attempts to modulate vasomotor tone pharmacologically.^{12,13} These studies showed that the act of walking had a marked positive effect on lamellar perfusion and interstitial glucose concentrations, moreso than just repeated unloading of the limb in a static/standing horse, indicating that the weight-bearing phase itself (and perhaps the movement of the limb associated with break over) may play an important role in lamellar perfusion. The potential mechanisms that might impair lamellar microvascular perfusion in the supporting limb of a clinical patient are likely to be more complicated than simple arterial occlusion alone, with postcapillary venous and interstitial pressure within the digit also likely to be affected by increased load and reduced load cycling on the supporting limb. The contribution of systemic inflammation and endocrine dysregulation (implicated in other forms of laminitis) to the development of SLL is also unclear; however, many SLL cases in clinical practice are complicated by infection and presumably suffer at least transient periods of insulin dysregulation during treatment for their primary injury² although this has not yet been studied.

3. Prevention

It seems that cyclic loading and unloading of the feet plays an essential role in digital homeostasis. In a horse that is preferentially weight bearing on one limb, it is currently not clear whether static or dynamic manipulations of the supporting limb (using orthotics or other devices) are sufficient to improve lamellar perfusion and energy balance without intermittent complete unweighting of the limb; however, studies specifically evaluating this are underway. The key to SLL prevention is likely to be the development of strategies to monitor and then regulate mean load and load-cycling frequency in the supporting limb of patients at risk. Monitoring should include some form of serial assessment of limb-load cycling—human pedometer devices and fitness tracking devices that incorporate accelerometers can track limb load cycling over time and may be of use clinically. In horses at risk, regular encouragement to walk may be beneficial; however, there is insufficient data to support specific recommendations at this stage and the logistics of this may depend on the nature and severity of the primary condition. Strategies to reduce weight on the supporting limb may include partial and preferably dynamic sling support and periodic forced or encouraged recumbency. Although sedation may help to encourage recumbency, it also reduces voluntary ex-

ercise and limb load cycling in stabled patients and therefore may be contraindicated. Effective analgesia to control pain in the primarily affected limb will help to encourage more normal weight-bearing patterns in the supporting limb. The use of non-steroidal anti-inflammatory drugs, opioids, and multimodal or regional analgesic techniques have been reviewed in detail elsewhere.¹⁴

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Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

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Treatment of Complications of Laminitis

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1. Introduction

The complications that will primarily be covered in this lecture are those dealing with injury and sepsis to the sole and subsolear tissue in the acute and chronic laminitis case. Whereas “acute” has been commonly used to describe the laminitis case in which displacement of the distal phalanx is not detectable by radiographs, it is being used here as a temporal term indicating that the disease has only been occurring for several days. Similarly, the term “chronic” is used by the author to describe the laminitis case in which foot pathology related to the original laminitis event (or recurring events) has been ongoing for several weeks to years.

2. The Acute Case

The most common complications dealt with in laminitis cases are those related to excessive solear pressure due to a rapid displacement of the distal phalanx. The distally displacing distal phalanx not only puts excessive pressure on the keratinized sole, but also disrupts the underlying dermis, which contains the vascular supply for the solear epithelium and the innervation for the sole. In the severe, acute case of laminitis (most commonly either sepsis related or supporting limb laminitis), the distal phalanx may perforate the sole, most commonly imme-

diately cranial to the apex of the frog. However, in cases of asymmetrical distal displacement of the distal phalanx (commonly termed “medial sinking” due to the fact that distal displacement of the medial aspect is much more common than the lateral aspect), the sole overlying the displaced aspect of the distal phalanx (commonly the medial sole) may be affected between the frog and hoof wall. In the acute case of laminitis, in which a rapid descent of the distal phalanx has resulted in perforation of the sole, both the perforation itself and the immense lamellar instability that led to the perforation are of great concern for treatment. The major concerns are attempting to neutralize the forces leading to the acute perforation, while also treating the injured region of the sole. A lateral and dorsopalmar radiograph are essential to assess the position of the distal phalanx. Solear perforation at the toe most commonly occurs with some degree of capsular rotation (divergence of the dorsal surface of the distal phalanx from the hoof wall) of the distal phalanx evident on radiographs. If phalangeal rotation (divergence of the dorsal surface of the distal phalanx from the normal phalangeal axis resulting in flexion of the distal interphalangeal joint) is also present, deep digital flexor tenotomy is commonly performed (more commonly in chronic cases) to decrease the tension the deep flexor tendon applies to the palmar/

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Fig. 1. Open sole cast application for acute perforation of the sole to improve weight bearing (A). Note that the foot impression material can be placed in unaffected sole and frog for support while affected regions can be left exposed for assessment and treatment (B).

plantar aspect of the distal phalanx. However, even in the case of capsular rotation with minimal phalangeal rotation, deep digital flexor tenotomy anecdotally helps some horses. Inferior check ligament desmotomy has been described as an alternative to deep digital flexor tenotomy both anecdotally and in case reports, but, to the author's knowledge, no in-depth study has been published on its efficacy for treatment of laminitis. Although many veterinarians maintain the foot in temporary shoes^a (e.g., wooden shoe applied with screws and/or cast tape) in these cases, due to the marked instability of the lamellae in many of these acute cases, it is possible that therapeutic shoeing may not provide enough protection from the forces to which this weakened tissue is exposed. Both open sole half limb casts (Fig. 1) and foot casts have been applied in attempt to neutralize as much of the downward force as possible.¹

3. The Chronic Case

Solear disease is a common complication in the animal with chronic laminitis also, and in the author's experience, is the most common cause of foot pain (vs lamellar pain) in the long-term case of laminitis. It is not uncommon for the lamellae to be stable in the chronic case, but for constant injury to the sole and dorsodistal aspect of the distal phalanx to be causing pain due to both an abnormal orientation of the distal phalanx and the commonly thinned/compressed sole. With regard to solear disease in the intact sole (i.e., not perforated), the injury can range from subsolear bruising to seroma and/or abscess formation.

The most common abnormalities associated with the distal phalanx (DP) in the chronic cases is an aseptic pedal osteitis, where the solear margin of the displaced aspect of the DP (most commonly the toe region), seems severely mottled (Fig. 2B) due to constant bruising and inflammation. Given that these bony changes are commonly present in the chronic case with subsolear abscess formation, the clinician needs to determine whether there is actually a septic pedal osteitis present before considering curetting the DP. For septic osteitis to be present, a focal region of severe bony lysis should be identifiable on radiographs (Fig. 3A). If there is only a general "moth-eaten" appearance to the solear margin of the DP (Fig. 2), it is advisable to not curette the DP and concentrate on treating the subsolear sepsis.

When assessing the solear region, it can be difficult with an intact sole to determine whether there is an underlying seroma or abscess. It is always advisable to obtain radiographs (three views: lateral, dorsopalmar [0 degree], and 60 degree dorsopalmar/solear margin) before exploring the sole to 1) determine the position of the distal phalanx (i.e., is it immediately

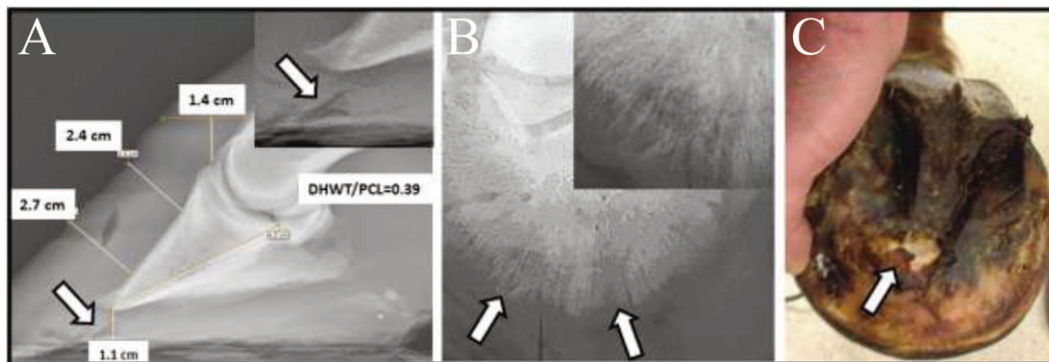


Fig. 2. A horse presented with a 7-day history of severe bilateral forelimb lameness with draining tracts on the solear surfaces of both feet. Radiographic measurements indicated a chronic distal displacement of the distal phalanx, and a focal lucency in the solear tissue immediately distal to the dorsodistal aspect of the distal phalanx (A, arrows in main image and magnified inset). Due to the somewhat diffuse nature to the bone resorption on the solear margin (B, arrows in main image, magnified inset), the bone was not curetted (deemed to most likely be aseptic resorption/"osteitis") and the feet treated only with soaks in a commercial chlorine solution until dry (C, arrow), at which time the lameness resolved.

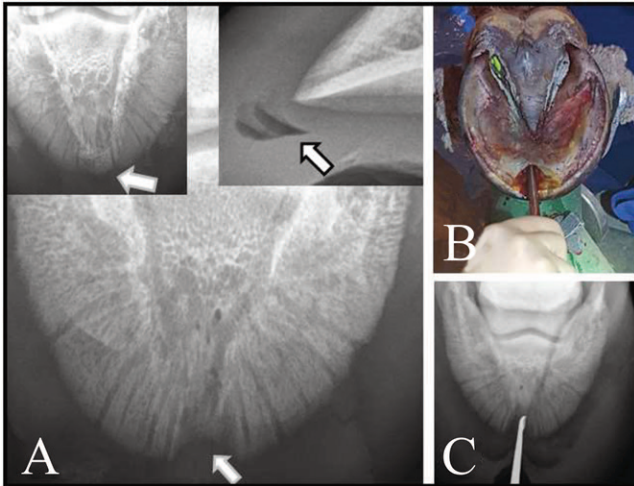


Fig. 3. A focal lucency noted on the dorsal aspect of the distal phalanx (A, arrow) in a chronic laminitis case with recurrent abscesses rupturing at the coronary band. Note the lack of the same lucency on the opposite foot (A, left inset, arrow) indicating that this is not normal anatomy for this horse (i.e., a crena), and the presence of gas lucency only at the toe (A, right inset, arrow) again indicating this region to be affected. The affected bone was curretted in the standing horse through an existing defect in the sole (B) under radiographic guidance (C).

above the solear surface), 2) assess for existing abscesses, and 3) assess the health of the margin of the distal phalanx. On radiographs, the abscess cavity usually cannot be visualized until drained (the purulent material is a similar density as tissue). If abscesses have established drainage at some point (commonly through “graveling out”/exiting at the coronary band), gas can commonly be observed on radiographs (white arrows in insets in Figs. 2A and 3A [right inset], and white arrows in Fig. 4A).

The primary goal of the author in cases of abscessation is to not only remove all offending debris and organisms, but to remove all moisture from the affected area (i.e., result in a “dry” lesion). It is common in chronic laminitis cases to have an extensive area of the sole affected by an abscess (Fig. 4A). In these cases, it is unlikely that immersion of the foot (i.e., in Epsom salts) will satisfactorily reach all areas in these cases or will result in removal of all moisture from the affected area. In the author’s opinion, it is important to establish multiple small openings to allow both drainage and active lavage of the abscess. If there is a thinned area which, upon palpation, is suspected of containing fluid (i.e., either seroma or abscess), the author will make a small entry (approximately 3–4 mm), assess any exudate, and probe the affected area to determine the size of seroma or abscess (a nerve block may be necessary to provide analgesia for probing the region). Another similar-sized opening can be made at a distant margin of the undermined pocket, and a syringe tip, catheter, or teat cannula inserted to flush with saturated Epsom salts (300–400 mL)

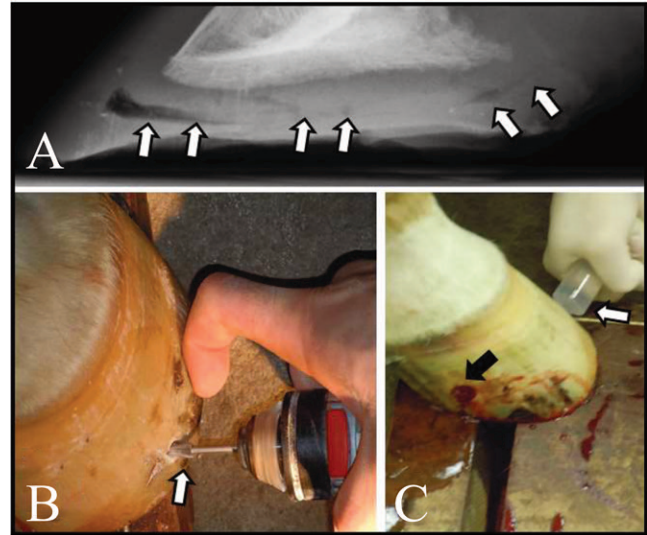


Fig. 4. Note the presence of gas density throughout the sole between the distal phalanx and ground surface of the sole (A, arrows) indicating an extensive (commonly termed “underrun”) abscess. The abscess cavity was accessed through the hoof wall (B) to obtain a dorsal access/drainage point, leaving the sole intact. The abscess could then be flushed (C, white arrow) under pressure with saturated Epsom salts (C, fluid can be seen exiting an opening on the opposite hoof wall through which a sequestrum was removed (black arrow).

once to twice a day. If there is a large undermined area affected by an abscess which is apparent on radiographs (Fig. 4A) but the sole is still intact, the abscess can be accessed through the hoof wall (Fig. 4, B and C). The advantages of accessing through the hoof wall are 1) the ease in protecting the openings (i.e., with tape), 2) no pressure will be placed on the region during weight bearing, and 3) extensive shoeing (i.e., with a pad or treatment plate) are not necessary to protect the area. With slightly larger openings to the area, the additional soaking of the affected foot/feet in commercial chlorine-related compounds^b, more commonly used for white line disease, can result in a rapid response. These compounds kill the offending organisms while also drying out the affected areas (a critical aspect of treating the affected foot), providing a much more rapid response than traditional foot soaks. In many chronic cases with subsolear abscessation in which a solear perforation is already present, the use of soaks with a chlorine compound are commonly all that is necessary. If the horse is severely lame on the one digit in the laminitis case, there is always a concern that laminitis may recur in the opposite limb now bearing the majority of the weight. In these cases, an open sole cast (Fig. 1) can be used, allowing lavage of the affected area while usually improving the lameness due to the support the cast provides.

In addition to approaching the subsolear injury directly, it is also important to address the abnor-



Fig. 5. Application of a plastic shoe^a in a case being treated for sequestrum removal from the distal phalanx.

malities in the digit that predisposed the sole to injury. This will include therapeutic trimming and shoeing, and possibly surgical techniques such as deep digital flexor tenotomy. These techniques have been recently covered at AAEP and will not be covered in detail in this presentation.

In the horse in which subsolear abscessation recurs in the same general region (either with solar drainage or rupturing/"gravelling" at the coronary band) even with the above therapies, septic pedal osteitis should be suspected. In addition to a focal lucency in the solar margin of the distal phalanx (Fig. 3), one or more bony fragments may be visible within the lucency. Surgical debridement of the region is required in these cases. Although easier to perform under general anesthesia, most cases can be treated in the standing horse with local anesthe-

sia. If the surgery is to be performed standing, the author commonly has the foot scrubbed then soaked in a commercial chlorine compound^a immediately prior to surgery. If there is a drainage tract in the foot, either a curette or probe is placed in the tract and radiographs are taken to gauge the depth and angle at which the distal phalanx should be curetted. Similar to that described for subsolear abscesses, if the sole is intact, it is preferable to approach the sequestrum through the hoof wall (Figs. 4, B and C). This is again a large advantage due to ease of access for further therapy (either irrigation or application of antiseptic-soaked gauze sponge), and ease of protection (only tape needed vs a removeable shoe or treatment plate). The other advantage is extremely rapid healing.

If a solear defect is present and needs to be protected between treatments, the author prefers taping on a temporary plastic shoe, most commonly using a commercial shoe^a and, taking one of the wedges off the shoe (Fig. 5). For many veterinarians and owners, it is easier to remove (and reapply) the taped-on shoe daily than to work with the bolts on a treatment plate.

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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^aNANRIC Ultimate, NANRIC, Lawrenceburg, KY 40342.

^bCleanTraxi, Equine Technologies, Inc., Sudbury, MA 01776.

How to Prepare for Endoscopy for the Equine Practitioner: Getting a Closer Look

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1. Introduction

Endoscopy of the equine upper airway is a useful tool to diagnose pathologic conditions of the nostrils, nasopharynx, larynx, guttural pouches, and trachea. The objectives of this paper are to provide an overview of necessary equipment for the equine practitioner to address upper airway conditions.

2. Materials and Methods

Endoscopic equipment was researched and, when possible, utilized for diagnostics of the equine upper airway.

3. Results

Flexible endoscopes are available in a variety of lengths, diameters, and configurations. The length of the scope will determine the specific regions that can be examined. Endoscopes of approximately 1 m allow visualization of the upper airway, whereas a 3-m endoscope is typically necessary to view the length of the equine esophagus and stomach. Prior to purchase of an endoscope, it is important to know what areas you intend to examine and to know all necessary parts of the equipment included in your purchase. The term endoscope can be used to describe the entire system but often refers only to the flexible instrument that is inserted into the nasal

passage of the horse. Images can be viewed through an eyepiece or on a monitor, allowing multiple users to view the display. Light delivery is necessary to illuminate the visible structures and surfaces of the airway. Image capture is a beneficial part of the system because it aids when communicating with horse owners and allows images to become a permanent part of the medical records. Working channels allow aspiration of samples, lavage of surfaces, or delivery of medications. A device to allow flushing of water or other liquids is also a beneficial accessory, especially in horses with significant airway or gastric secretions. Endoscopic systems can be divided into three main categories: portable, semi-portable, and tower systems. The power supply for portable systems is typically a battery. Although this avoids the necessity of plugs and power cords, it does require periodic charging, battery maintenance, and replacement. Although new units are nice, demo units or previous-generation equipment can be purchased at a lower cost and might be easier to justify when starting out or until a large-enough client base is established to demand regular use. Service contracts should be considered for the flexible endoscope portion of your system, given that this portion will undergo higher failure and accident rates than the remainder of the system. Endoscopy

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systems require cleaning and for some procedures sterilization between patients. Cleaning of the flexible scope, as well as all handles and dials, is important to prevent disease transmission between patients. Endoscopy units should be pressure checked prior to cleaning, to determine whether the channel linings hold pressure and have not sustained penetrating damage that could allow liquids and antiseptic fluids to leak into the sensitive inner regions of the equipment. This is especially important after utilizing the working channel for biopsy or aspiration, given that these events can predispose to channel lining damage.

4. Discussion

Practitioners looking to expand the diagnostic capabilities of their practice are likely to see a benefit from purchase of an endoscope: a wonderful addition to work up common problems. The respiratory tract, guttural pouches, oral cavity, esophagus, and stomach can all be viewed and evaluated with an endoscope. In addition, the equine stomach can be evaluated, making the diagnosis of gastric ulceration a possibility, which at times is as easy as passing a stomach tube, although understanding the anatomy of the stomach as well as how to manipulate the endoscope is important to be able to visualize all portions of the stomach including the gastric outflow tract and proximal duodenum. Gastros-copy is a very practical means to identify or rule out

gastric ulceration and is used to grade ulcer severity and monitor treatment. Endoscopic equipment can be sterilized and used to examine the urinary tract to evaluate horses for cystic or urethral calculi, mass lesions, or infections.

Respiratory endoscopy is primarily used to examine horses that present for poor performance or horses reported to have abnormal breathing sounds. Without sedation, the endoscope is passed up a nostril and the nasopharynx and larynx can be evaluated for resting function. Some horses with abnormal breathing might only show problems during exercise. These patients could benefit from endoscopy performed with the horse exercising on a treadmill or perhaps using a portable system mounted on the horse or rider while the horse is being ridden or driven. This equipment will allow capture of images from lesions seen only during a dynamic examination. For respiratory problems beyond the larynx, the endoscope can be passed into the trachea. Cytologic analysis of the deep airways can aid in an individualized treatment plan.

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Upper Airway: Standing Endoscopy Versus Dynamic Endoscopy: A Case-Based Approach to Navigating Appropriate Uses for Each

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1. Introduction

History, physical examination, laryngeal ultrasound, and upper-airway endoscopy are all important aspects of evaluating the upper respiratory tract. Additional diagnostics such as a dynamic examination of the upper airway may be required to elucidate the problem(s) causing an abnormal respiratory noise and/or exercise intolerance. Evaluation of the upper airway during exercise allows the clinician to determine whether the horse has a dynamic upper airway abnormality and then make the most accurate treatment recommendation.

2. History

A complete and thorough history is a very important part of the upper airway evaluation. It is best to obtain this information from the individual(s) who know the horse best. Most often this is the trainer or rider and may not be the owner of the horse. Specific questions regarding respiratory noise, exercise intolerance, coughing, nasal discharge, previous surgery, and current or previous treatments should be asked. Information regarding whether the noise is made during inspiration or expiration is very helpful but oftentimes it is not accurate because the

owner/trainer/rider has not listened for that specifically. Try to determine whether the abnormal noise occurs every time the horse works or if it is intermittent. In addition, ask questions to determine at what point during exercise the horse makes the noise. Another very important piece of information, especially in horses that show “collected” or with poll flexion is: does the head position of the horse affect respiratory noise? It can be helpful to have the individual describe and characterize any abnormal respiratory noise(s) that the horse makes. It is important to determine whether the horse is exercise intolerant and/or exhibiting poor performance.

3. Physical Examination

Begin the physical examination with auscultation of both sides of the thoracic cavity. The heart rate, rhythm, and the presence of a cardiac murmur are determined. A rebreathing examination is important to evaluate the lungs. Remember that disease(s) of the lower airways and lungs do not cause upper-respiratory noise. Visual assessment of the head and nares should be performed to evaluate for asymmetry. Evaluate both nostrils for the presence of airflow and determine whether it is equal.

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Evaluation of the head and both eyes for the presence of any cranial nerve deficits should be performed. Each jugular vein should be evaluated for patency. Palpation of common surgical sites should be performed to check for scars. Palpation of a laryngoplasty scar can be difficult but clipping of the hair just ventral to the linguofacial vein can help you determine whether a scar is present. Palpation of the trachea should be performed to assess whether the horse has had previous trauma, malformed tracheal rings, or a tracheotomy performed in the past. Palpation of the larynx to assess for symmetry should also be performed. This skill is not easy and requires practice to become proficient. Abnormalities such as a prominent muscular process as felt in cases of laryngeal hemiplegia or the lack of a cricothyroid articulation as felt in cases of laryngeal dysplasia are important physical examination findings. Historically the slap test was used as another method to evaluate laryngeal adductor function. This test has been shown to be ineffective in differentiating normal from abnormal laryngeal adductor function and the author does not recommend using it as part of an upper airway evaluation.¹

4. Upper Airway Endoscopy at Rest

Endoscopy of the upper airway is then performed. The resting endoscopic examination is very important to determine whether there are any structural or anatomic abnormalities present. Dynamic abnormalities or problems that only occur at exercise will not be detected during the resting examination. The clinician may get a sense of what is happening at exercise but an evaluation of the airway at exercise is the only way to determine whether a dynamic problem exists. The horse should be restrained if necessary but not sedated. Sedation can affect the function of the larynx, thus making assessment difficult.² Following sedation the horse may exhibit asynchronous arytenoid movement or the inability to fully abduct one or both arytenoid cartilages. Therefore it is advisable to avoid sedating the horse to avoid these potential problems. Common methods of restraint include twitch, lip chain, neck skin roll, and ear twitching. Some horses can be evaluated without using any of these techniques. The endoscope is passed up the right nasal passage to the level of the nasopharynx. The nasopharynx should be evaluated for structural and functional abnormalities. The width of the nasopharynx at the level of the guttural pouch openings should be assessed. Horses that have collapse of the lateral pharyngeal walls during exercise often are very narrow at this location. The width of the nasopharynx is a subjective assessment and the clinician should be cautious about predicting the occurrence of a dynamic problem (lateral pharyngeal collapse) from a resting examination. Nasopharyngeal cicatrix formation can be seen as scarring ranging from a focal area to involvement of the entire circumference of the nasopharynx. This abnormality is seen in

horses from hot climates such as Texas, Louisiana, Mississippi, Oklahoma, and Florida. The ethmoid turbinates and nasomaxillary sinus opening should be examined. Abnormalities that could cause respiratory noise include an ethmoid hematoma that is causing an obstruction in the nasal passage or a mass protruding from the nasomaxillary opening obstructing the airway. Both guttural pouches should be evaluated. Abnormalities that could be encountered include guttural pouch empyema, chondroids, enlarged retropharyngeal lymph nodes, stylohyoid bone abnormalities, lymphoid hyperplasia, and guttural pouch mycosis. These abnormalities do not directly cause abnormal respiratory noise but they may lead to a problem such as dorsal displacement of the soft palate. The epiglottis should be evaluated for any structural abnormalities. The most common abnormality would be epiglottic entrapment. Some clinicians take note of the length and consistency of the epiglottis as well. The ventral surface of the epiglottis should be evaluated for ulceration. This can be performed by elevating the epiglottic cartilage using a grasping instrument passed up the contralateral nasal passage. The position of the soft palate with respect to the epiglottis should be assessed. Some horses will displace their soft palate during the resting examination and replace it after one to two swallows. Nasal occlusion is often used to assess soft-palate function but the clinician must remember that this test is not a replacement for a dynamic examination. The degree of pharyngeal lymphoid hyperplasia can be characterized. There is a grading system from one to four.³ A Grade I would have a small number of inactive (white in color) lymphoid follicles spread across the dorsal aspect of the pharynx. A Grade II would have inactive as well as active lymphoid follicles (edematous and pink in color) spread across the dorsal aspect of nasopharynx to the level of the guttural-pouch openings. A Grade III would have larger active follicles that may extend to the level of the soft palate. A Grade IV would have coalescing active lymphoid follicles. Having severe lymphoid hyperplasia does not directly cause abnormal respiratory noise but the severe inflammation may lead to problems such as pharyngeal collapse or dorsal displacement of the soft palate, which would cause the abnormal respiratory noise. Each arytenoid cartilage should be evaluated for structure, symmetry, and movement. The shape and thickness of each arytenoid cartilage should be assessed. A granuloma can form on the medial surface of the corniculate cartilage while the remaining portion of the arytenoid cartilage or its movement is not affected. The movement of the arytenoid cartilages should be evaluated during normal resting respiration, after swallowing, and during nasal occlusion. The goal is to determine whether the structure of the arytenoid cartilages and the degree of abduction are normal. A grading scheme is used to categorize arytenoid symmetry and movement.⁴ A Grade I

has synchronous and symmetrical movement. A Grade II.1 has transient synchronous or asymmetrical movement but maximal abduction is easily achieved. A Grade II.2 has asynchronous or asymmetrical movement most of the time and maximal abduction is achieved but with difficulty. A Grade III.1 has asynchronous or asymmetrical movement and cannot maintain full abduction. A Grade III.2 has limited arytenoid movement and cannot fully abduct. A Grade III.3 has marked but not total abductor deficit. A Grade IV lacks any arytenoid movement (completely paralyzed). Then examine the right nasal passage as the endoscope is withdrawn. The nasal turbinates should be inspected for swelling, masses, or foreign material. The endoscope is then passed through the left nasal passage and the left ethmoid, nasomaxillary opening, and left guttural pouch are inspected. The trachea should be evaluated for signs of infection, hemorrhage, tracheal ring defects, granuloma formation, and for signs of prior trauma or surgery. In the typical 450-kg horse the trachea can be examined nearly to the level of the tracheal bifurcation using a 1-m endoscope. The left nasal passage is then examined as the endoscope is withdrawn. Both nasal passages, both guttural pouches, and the trachea should be evaluated in each horse presented for a respiratory evaluation. Laryngeal ultrasound provides a noninvasive technique to gain information regarding the laryngeal cartilages and musculature.^{5,6} There are numerous upper-airway abnormalities that can be diagnosed using standing endoscopy alone. The following are some examples of conditions that can be diagnosed using resting endoscopy:

Epiglottic entrapment, subepiglottic cyst, persistent dorsal displacement of the soft palate, laryngeal hemiplegia, arytenoid chondritis, laryngeal dysplasia, and arytenoid granuloma formation. However, a dynamic examination may be required to get the full picture of the horse's airway.

5. Upper Airway Endoscopy During Exercise

There are many reasons to perform an endoscopic examination of the upper airway while the horse is exercising/working. The dynamic examination can be performed while the horse is exercising on a high-speed treadmill or by using overground or remote endoscopy. The following are a basic list of reasons:

- The horse makes an abnormal respiratory noise and has a normal resting endoscopic examination.
- The horse has an endoscopic abnormality at rest and you want to assess the effect at exercise.
- Poor performance (with or without abnormal respiratory noise).
- Screening test/pre-purchase examination.
- Assess the efficacy of a previous upper airway surgery.

Examination on a high-speed treadmill should not be taken lightly. It can be very dangerous for the horse and people performing the examination. Problems do not occur very often but there is always a risk for injury. However, this is the case with any horse that is being exercised. In order to get an accurate assessment of the horses' airway function the treadmill examination must mimic the type of work the horse does. It is very important for show/sport horses to have the same head and neck carriage when they are working on the treadmill as they do when showing. Make sure the trainer/owner brings the necessary gear to set their head. Standardbreds should have their harness (including hobbles if necessary). Thoroughbred racehorses typically do not need any special tack. Prior to the examination, discuss with the trainer if the horse is currently in work, their level of fitness, and how much work they are doing. It is also important to find out under what circumstances the horse exhibits the abnormality. Is it early in the workout? At the end of the workout? Once a certain speed is reached? When the head is in a certain position, etc.? Reviewing a race record can yield helpful information regarding the distances and race times that the horse is achieving. Once you have determined that the horse is fit enough and does not have a musculoskeletal reason that would preclude it from strenuous exercise, it is time to acclimate the horse to the treadmill.

The hind shoes are typically removed (leave the front shoes on) from the Thoroughbred racehorses but the shoes are left on the other breeds. The shoes are very important for proper gait in most of the show horses so do not remove them. Protective gear such as bell boots and sports-medicine boots are helpful to prevent injuries. Standardbreds will often wear knee boots or other protective equipment. A resting endoscopic examination should be performed in addition to a physical examination. The horse will be walked through the treadmill a few times to get them comfortable with the footing and side bars. The horse is then taught to walk on the treadmill. Once they are comfortable walking the pace will be increased to a trot then gallop if that is an appropriate gait for the horse. The acclimation process gives the horse a chance to get comfortable with the treadmill as well as warm up for strenuous exercise. Most horses acclimate quickly. However, there are certain horses that are difficult to acclimate and more time is necessary. It is a big mistake to rush the process—injury to the horse, people, and/or damaged equipment will be the end result. There are horses that are not safe to treadmill and the procedure should be abandoned. During the acclimation phase watch for signs of lameness—if present, perform a thorough lameness examination prior to increasing the exercise intensity. Once the horse is acclimated and comfortable working on the treadmill, the endoscope should be

passed up the right nasal passage (or left depending on how the treadmill is set up) and secured to the nose band on the halter. There are a variety of ways to secure the scope in position. The scope should not be so secure that it will be damaged if the horse decides to go backward. Positioning the end of the endoscope in the nasopharynx is very important. The tip of the endoscope should be rostral to the epiglottis but not so far rostral that you do not have a good view of the larynx. Once the endoscope is positioned and secured, the treadmill examination should commence. Ensure that the video recording device is capturing video. A recording device is critical to document the examination and allow you to replay the video in slow motion for critical evaluation. The treadmill speed is increased until the appropriate speed is reached. The horse's gait and speed are dependent on the type of work the horse performs. For example, a Thoroughbred racehorse should be galloping at race speed. The clinician must watch the video endoscopy as well as have awareness of how the horse is doing on the treadmill. During the examination, listen for abnormal respiratory noise and correlate that noise with the video image. If there is abnormal respiratory noise and no visible abnormality, then the problem is either rostral to the end of the endoscope or caudal to the larynx. Repositioning of the endoscope will be necessary and the examination repeated. The speed may need to be increased, decreased, or maintained. Once the examination is completed then the endoscope should be removed and the horse is cooled out. During this time the video endoscopic examination can be reviewed. It is crucial to have slow-motion review capabilities to fully assess the airway.

The initial workup is the same whether the clinician is planning to perform a treadmill or overground examination. The ability to perform overground or remote endoscopy allows the clinician to examine the horse in the exact environment and type of work that the horse typically performs. This is very important so that the clinician gets an accurate assessment of the horse's upper-airway function during exercise. In the author's opinion, overground endoscopy is superior to endoscopy while exercising on a treadmill when evaluating sport horses or show horses. It is very hard if not impossible to replicate the type of work these horses are performing by evaluating them on a treadmill. Rider influence is an important component that is lost when using a treadmill. The endoscope should be positioned in the nasopharynx so that the clinician has an appropriate image of the upper airway. Care must be taken so the endoscope is not positioned too close or too far away from the larynx. You must also factor in the effect of a change in head position while the horse is at work compared with resting. The horse should be tacked up and the endoscope should be positioned appropriately. The order in which the tack and endoscope are placed

will depend on the system that you are using. The horse should be warmed up and then examined. While the horse is warming up, the position of the endoscope can be assessed and changed if necessary. Prior to starting the examination, the recording device should be turned on and made sure that video is being captured. It is critical that the horse is worked in the same manner that creates the "abnormality." The big advantage of overground endoscopy is that horses can be examined in essentially the exact manner that causes the upper-airway abnormality. Post-exercise evaluation of the overground examination is the same as described above.

There are multiple dynamic abnormalities that can occur in the upper airway. The list includes but is not limited to the following: intermittent dorsal displacement of the soft palate, medial deviation of one or both aryepiglottic folds, pharyngeal collapse, medial deviation of one or both vocal cords, collapse of one or both arytenoid cartilages, epiglottic retroversion, tracheal collapse, billowing of the rostral aspect of the soft palate, epiglottic entrapment, and combinations of these problems. This type of examination allows the clinician to determine which treatment options are necessary and/or feasible. There are certain abnormalities or combinations of abnormalities that may not have a viable treatment.

In summary, resting and dynamic or overground endoscopy are vital to making an accurate diagnosis in a horse with a suspected upper airway problem. There are instances where a resting examination is all that is needed to make a diagnosis such as a case with Grade IV left laryngeal hemiplegia. However, the clinician must remember that resting endoscopy is often a very poor indicator of upper airway function during exercise. It is advisable to take a stepwise approach when trying to determine whether a horse has an upper airway problem that is causing poor performance. The steps include taking a detailed history, a physical examination, and performing a thorough resting endoscopy. Based on these findings a dynamic or overground endoscopy may be required to fully evaluate the horse's upper airway function. The list of reasons to perform a dynamic endoscopic examination include, but are not limited to, the following:

- The horse makes an abnormal respiratory noise and has a normal resting endoscopic examination.
- The horse has an endoscopic abnormality at rest and you want to assess the effect at exercise.
- Poor performance (with or without abnormal respiratory noise).
- Screening test/pre-purchase examination.
- Assess the efficacy of a previous upper airway surgery.

Acknowledgments*Declaration of Ethics*

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Conflict of Interest

The Author has no conflicts of interest.

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How to Examine and Grade the Upper Airway at Public Auction

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1. Introduction

Endoscopic evaluation of the upper airway of horses presented at public auction is an important part of the overall assessment of sales horses for suitability for either racing or resale. Although considered a common and relatively simple procedure, there are aspects to the examination that can make it simpler to perform and more understandable for both sellers and potential buyers.

First of all, in order to facilitate the passing of the endoscope, it is advantageous to use an endoscope with a small diameter (fiberoptic endoscope with a 7.6-mm diameter that is relatively well tolerated by horses of all ages). This will decrease the discomfort that the horse experiences and therefore facilitate the passage of the endoscope. Also, once the distal tip of the endoscope has been introduced into the nares, the fingers should no longer contact the nares while advancing the scope given that horses tend to object to that contact and will settle down once nasal manipulation has ceased. This is important because many of the horses presented for sale at public auction will be scoped multiple times within 1 or more days prior to the sale so good technique can minimize a horse's discomfort and possible trauma to horse and/or handler. Most veterinarians are introducing the scope into the right

nares, but that is not universal. It must be remembered that as the scope is advanced to the level of the pharynx and larynx, there is by definition only one nasal passage being evaluated for any potential pathology regardless of which nares is entered. This is unlikely to be an issue in a population of primarily normal horses, but in the context of a horse with clinical signs of airway insufficiency both sides should be evaluated for a complete examination.

As in most medical procedures, the correct interpretation of the findings is more challenging than the actual performing of the procedure. In the case of upper airway examination and evaluation, it is not only the interpretation of the findings but the communication of that information to clients and colleagues that requires a standardized system. The use of a standardized system enhances the ability to describe the upper airway and communicate the findings with colleagues and clients. It is important that a standardized grading system for the upper airway incorporate the elements of being as objective as possible and easy to understand while being descriptive of the areas of interest. There are two standardized systems in current usage, the Havemeyer and the Modified Cornell.¹⁻³ They are both standardized classification systems based on description of arytenoid function. The grade

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categories range from Grade 1 to Grade 4 with several subcategories. The number “1” is synonymous with the word “symmetric,” so Grade 1 arytenoid function means that the arytenoids open symmetrically, fully abduct, and hold their position. The number “2” is synonymous with the word “asymmetric.” Grade 2 function means that the arytenoids open asymmetrically, fully abduct, and hold their position. Grade 2 function is broken down into two categories, 2A and 2B (Modified Cornell) or 2.1 and 2.2 (Havemeyer). The “A” of 2A is synonymous with the word “mild.” A 2A or 2.1 designation would mean that the arytenoids open mildly asymmetrically, fully abduct, and hold. Similarly, the “B” of 2B is synonymous with the word “moderate.” Thus, a 2B or 2.2 designation means that the arytenoids have a moderate level of asymmetry when abducting, but the abduction is full and the arytenoids are able to hold in the fully abducted position. Grades 1, 2A, and 2B (or 1, 2.1, and 2.2) arytenoid function are all variations of a normal upper airway. Statistically there is no difference in the racing performance of horses with Grade 1, Grade 2A (2.1), and Grade 2B (2.2) function (note: present research suggests that racehorses with Grade 2B function are equivalent in earnings with their Grade 1 and 2A counterparts at age 3 years, but have decreased earnings at 2 and 4.^{4,5a}

Grade 3 function is the designation for an arytenoid that may either achieve abduction only transiently and with difficulty or may not fully abduct. There are three subdivisions of Grade 3 function in the Havemeyer system to designate the level of compromised function. Grade 4 function is the designation reserved for an arytenoid that does not move (laryngeal hemiplegia). Grades 3 and 4 arytenoid function are not normal. Grade 3 and Grade 4 airways do not meet Conditions of Sale at all four of the Thoroughbred sales companies in the United States. In the author’s opinion, the Havemeyer and Modified Cornell systems for grading laryngeal function are similar enough that any veterinarian employing one of these systems can fully understand the alternate system.

The epiglottis is evaluated separately from arytenoid function. It is graded as normal, mildly flaccid, moderately flaccid, or severely flaccid. The length of the epiglottis is noted as normal or short. Interestingly, given that the epiglottis is under autonomic nerve control, the appearance of the epiglottis can change from examination to examination or even within the same examination. If during the examination the epiglottic appearance changes from moderately flaccid to completely normal, the author’s approach is to assume that the structure has the capability to achieve normalcy. It is difficult to use the appearance of the epiglottis as predictive of upper airway dysfunction because there is no scientific evidence correlating mild or even moderate flaccidity of the epiglottis to clinical dorsal displacement of the soft palate.⁴ The position of the epiglottis is

controlled by the hyoepiglotticus muscle, and its appearance can vary based on the degree of muscular contraction or relaxation.⁶ Eliciting swallowing during the examination can give the examining veterinarian an idea of whether there is dorsal displacement of the soft palate over the epiglottis, and if so whether the horse is able to easily replace the epiglottis in its normal position. Many horses at public auction will intermittently dorsally displace the palate due to nervousness related to new surrounding or the scoping procedure itself, and this should not be interpreted as predictive of clinical dorsal displacement of the soft palate creating airway insufficiency under racing conditions.⁴

Guttural pouches are noted for whether or not there is an exudate of any kind emanating from the orifice, and the pharynx is evaluated for the presence and magnitude of pharyngitis as well as any polyps or abnormal structures. It is very common at public auction for weanlings, yearlings, and 2-year-olds in training to exhibit pharyngeal inflammation manifested by varying degrees of pharyngitis and exudate emanating from the guttural pouch openings. In my opinion, these findings do not constitute a reason for avoiding a purchase, but rather are an indication that an individual may require treatment and further evaluation after purchase.

Conditions of Sale

All US sales companies have “Conditions of Sale,” some of which refer specifically to conditions of the upper airway. These are included to protect the buyer from purchasing a horse with an upper airway condition that would be acknowledged to be pathological. Already referenced would be the horse with either a Grade 3 or Grade 4 arytenoid function. In the sales catalog, this would be listed as laryngeal hemiplegia (complete immobility or inability to fully abduct the cartilage). Other airway abnormalities that are covered by conditions of sale are listed below:

- Rostral displacement of the palatopharyngeal arch
- Epiglottic entrapment
- Permanent dorsal displacement of the soft palate
- Severe arytenoid chondritis or arytenoid chondroma(s)
- Subepiglottic cyst(s)
- Cleft palate

For any of these conditions, a post-sale endoscopic examination of the upper airway is sufficient to protect the buyer as a horse with any of these conditions would be subject to return. (Note: rostral displacement of the palatopharyngeal arch and epiglottic entrapment may each be transient, which is obviously problematic when a horse has been deemed normal on a pre-sale basis and exhibits the condition endoscopically post-sale).

The value of the pre-sale endoscopic evaluation of the upper airway at rest in the stall has proven to be less predictive of airway performance since the advent of dynamic or over-ground endoscopy.^{7,b} The purpose of “holding off” the horses’ air during the resting endoscopic examination is to cause the horse to breathe deeply to observe maximal arytenoid abduction, but dynamic endoscopy gives a better picture of the function of the upper airway at something approaching racing distance. It has been observed that many (if not most) of the pathological conditions resulting in airway insufficiency as diagnosed by dynamic endoscopy would not have been evident during a resting endoscopic examination in the stall.⁸ For this reason, it is important for practitioners to be cautious in making certain predictions: for example, potential laryngeal hemiplegia based upon a resting arytenoid asymmetry, or predicting a clinical dorsal displacement of the soft palate based upon a resting examination where the horse displaces. The more information that we get from dynamic upper airway examinations, the more that we realize that resting endoscopy is a screening tool for more obvious findings.

For example, there is another condition which, although not yet covered by Conditions of Sale at any of the Thoroughbred auction houses, has in recent years been recognized to predispose horses to a higher incidence of airway collapse than endoscopically normal horses. Subluxation (ventroaxial luxation) of the apices of the arytenoid cartilages, and the recognition of this condition, requires that the horse’s air be held off to stimulate deep breathing and maximal arytenoid movement.⁹ This is accomplished by collapsing the external nares with the same hand that is holding the scope in place on the bridge of the nose and releasing the nares once the horse is breathing deeply. The actual airway collapse can only be appreciated under dynamic conditions. Similarly, during a resting pre-sale endoscopic examination in the stall, the width of the pharynx at the level of the guttural pouches is evaluated, and horses with a narrow pharynx have increased risk of lateral pharyngeal collapse, which can only be appreciated during a dynamic endoscopic examination.^b

In 2016 the idea of performing videoendoscopic exams of the upper airway of sales horses for pre-sale viewing at public auction resurfaced, and the American Association of Equine Practitioners (AAEP) was charged with providing guidelines for such examinations. The idea behind consignors providing pre-sale videos of the upper airway was to minimize the number of pre-sale scopes on any individual horse and thus minimize the potential for trauma to either the horses themselves or their handlers. An AAEP working group constructed the following Protocol for Pre-Sale Videoendoscopic Examination of the Upper Airway at Public Auction which was subsequently approved by the AAEP Board of Directors:

- Equipment must be capable of producing a digital video image of excellent quality.
- Horse must be identified appropriately, and that identification must be in digital format with character generation on the screen, and/or video of the catalog page, followed by unbroken video of the face prior to introduction of the scope into the nares (right or left) and up to the larynx. This is a single stream video with no editing. The veterinarian performing the video or the consignor will submit each upper airway video on an individual flash drive or CD. Upper airway videos should be stored in a file separate from the radiographs in the repository in case of client request for one or the other.
- Standard technique must include maximal abduction of arytenoids induced by swallowing (multiple times) and nasal occlusion. The duration of the video must be sufficient to identify all laryngeal and pharyngeal structures as well as observing their maximal function within the context of a resting examination.
- The interval between the pre-sale videoendoscopic examination and the selling session will not exceed 10 days.

The 10-day interval mentioned above was considered by all to be a compromise between the desire to evaluate the upper airway as close to the selling session as possible and the practicality of performing a large number (perhaps thousands) of videoendoscopic examinations in a short window of time (1–2 weeks). Ideally, buyers like their veterinarians to perform that examination either on the day of the sale or 1–2 days prior due to the possibility of a deterioration of the upper airway function during the time between the examination and selling date. The idea has been introduced that a condition of sale be created to ensure that the upper airway of the horse as observed endoscopically on a post-sale basis approximates the pre-sale videoendoscopic examination. An example of the wording that has been discussed for a new condition of sale would be:

Post-sale endoscopic examination of the upper airway must be performed within 24 hours of selling session while the horse is still on the salesgrounds. In the case that the upper airway does not meet conditions of sale as delineated in Condition ____, the horse shall be returned. In the case that the upper airway is significantly different from the pre-sale video but still technically meets conditions of sale, the seller may get an opinion from the veterinarian of his or her choice. If the opinions agree that the upper airway is significantly different from the pre-sale video, the horse shall be returned. If the first and second veterinary opinions disagree, a panel of three veterinarians will render an opinion and that opinion shall be binding.

Such a condition could be a potential solution to the timing of the videos, but is not currently being considered as the concept of upper airway videos at the sales is in its infancy. The positive result of such a condition would be that it addresses the issue of any changes that may occur in the upper airway during the 10 days between the pre-sale videoendoscopic examination and the selling session. The negative aspect of creating such a condition of sale would be that instead of a sale being final at the drop of the hammer, the horse could be subject to return even if its upper airway technically meets the traditional conditions of sale.

After the evaluation of the upper airway by endoscopy, it is important to communicate the findings to the client in a way that is understandable and conveys the information as risk assessment. Findings, in and of themselves, do not necessarily eliminate a horse from consideration for purchase. Especially in the case of pre-sale examinations, it is important to emphasize that the risk level is predicated upon observations regarding populations of horses, and that it is not possible to predict what will occur with any individual horse. For example, although Grade 2B arytenoid asymmetry is considered to be a variation of normal, many express concern that the examination is just one point in time and that a subsequent examination may reveal the asymmetry to have progressed to dysfunction. If the horse in question is presented for sale as a yearling, and may have had a Grade 2B arytenoid function score as a weanling, the historical information allows practitioners to report a stable arytenoid function over time. It is important to communicate all these considerations to the client while discussing their level of risk tolerance. Clients with greater understanding of the conversation typically have a higher risk tolerance, and they also understand that the upper airway findings are but one factor in the making of a racehorse, albeit an important one. Radiographic findings, pedigree, conformation, history, and other factors also play a part in a client's ultimate decision as to whether or not they will purchase any given individual horse.

In summary, the appropriate equipment and technique can greatly facilitate the examination of the upper airway under resting conditions at public auction. The anatomical areas of interest are the nasopharynx and larynx, with particular emphasis on the structure and function of the arytenoid cartilages as well as the appearance of the epiglottis. The endoscopic examination of the upper airway in the resting horse, when performed properly, is capable of detecting some structural and functional abnormalities, but is limited in the sense that there are some abnormalities that can only be detected under dynamic conditions (i.e., over-ground endoscopy). The purpose of pre-sale endoscopy is to not only identify observable abnormalities of the upper airway, but also to identify and describe variations of normal which may be interpreted differently re-

garding their level of risk by various veterinarians and thus affect the market value of the individual horse. A comprehensive discussion of how to communicate the aforementioned findings to sellers or potential buyers is difficult because each client has their own unique level of understanding and risk tolerance, so the suitability of any given individual horse may vary depending upon the client. In other words, the same horse may be suitable for one client but not another. This is true of all findings, whether they are endoscopic findings of the upper airway, radiographic findings of the specified joints in the repository radiographs, or physical examination findings.

Ideally, the examining veterinarian should strive to communicate to the client what is known from the literature regarding the upper airway examination:

1. Thoroughbred yearlings with Grade 1 and Grade 2 arytenoid function had significantly better racing performance as adults, compared with yearlings with Grade 3 arytenoid function.
2. Epiglottic flaccidity and palatine abnormalities were not predictive of inferior racing performance⁴; however, a short epiglottis was associated with decreased racing performance.⁵

The purpose of post-sale endoscopy is primarily to identify any abnormalities of the upper airway that would be covered by conditions of sale and therefore negate the purchase of the horse. Any variations of normal that would be identified on a post-sale examination should be communicated to the buying client as potentially affecting resale of the horse, but would *not* make the horse eligible for return to the seller.

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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How to Make Dental Endoscopy Part of Your Routine Oral Examination

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1. Introduction

The equine oral exam is the cornerstone of equine dentistry. In the past decade, the veterinary profession has fostered an increased interest in equine dentistry. This has led to the publication of scientific papers that have focused on the benefit of a thorough oral examination. Peer-reviewed papers have been published specifically on equine oral anatomy, oral pathology, and methods to perform the oral examination.^{1,2} The basic instruments needed for the oral examination, in a sedated patient, are a full-mouth speculum, a mouth mirror, and a bright light source. Documenting the oral exam findings has historically been through written text in a medical record or better yet recorded on an equine dental chart. Intra-oral images in the mouth have been obtained by taking a picture of the mouth mirror reflecting the pathology. This can be a difficult task in the standing sedated patient and image quality is less than desirable. Oral endoscopy can allow excellent visualization of the dentition with a convenient method of capturing images.

Technology has now become part of our everyday life as a practitioner. Modern equine practices now have the ability to capture and store

pictures pertaining to many aspects of the patient's medical record in their practice database. This bolsters the medical record for purposes of monitoring and communicating with other practitioners and owners. The equine oral cavity has challenges of examining structures in a dark tunnel that often does not lend itself to easily being photographed. A camera of a cell phone or a good digital camera has often been used in conjunction with a mouth mirror to capture images of pertinent pathology. Recently, boroscopes and small digital capture devices have become available for other industries that make capturing images in a wet, poorly lit environment possible. Peer-reviewed papers and textbook chapters have been published describing many uses of oral endoscopy systems.³⁻⁶

In this article, we will discuss the common devices that are commercially available and the components that can be individually sourced to build your own system. Pros and cons of each system will be discussed to aid the practitioner in purchasing the correct system for their practice. This is not a complete list of all endoscopic systems available for use in the oral cavity but rather a representation of systems that are being used routinely in the horse.

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2. Materials and Methods

The practitioner must identify their goal for use of oral endoscopy equipment. Questions that need to be answered:

1. Will the system be utilized in the field?
2. Will the system be utilized primarily to show the client their horse's oral examination?
3. Will the primary use of the system be to capture images for the medical record and/or for publication in medical journals?
4. Do you currently utilize endoscopy in your practice?

If the goal is high-resolution images for publication, this needs to be decided early in the progression of setting up your system so that a camera can be chosen that will produce high-resolution images. If the goal is to produce images for medical records and to demonstrate findings to the client, all the described systems in this paper will perform nicely. All equine patients receiving an oral exam can be examined with an oral scope.

The systems that are commonly utilized for oral endoscopy can be broken down into two categories:

1. Systems that are commercially available.
2. The do-it-yourself (DIY) systems where the practitioner compiles the components themselves.

Commercially Available Systems

These systems have a vast range in price, image quality, and function. The practitioner must decide for themselves what fits their budget and how this instrumentation will benefit their practice. Below is a list of commercially available systems from least expensive to most expensive. It is by no means a complete list but is a list of commonly used devices by practitioners.

1. Eezy-view camera^a
2. Portascope Dental stick^b
3. Stoll Oral endoscope package^c
4. Dr Fritz Dental Stick^d
5. MDS Scope source flexible endoscope^e

DIY-Assembled Systems

These systems are compiled from different sources such as Ebay™ or endoscopy instrument suppliers. Many imaging towers can be outfitted with a rigid endoscope to capture images in the oral cavity. There are a few important features of the system that need to be present in order to obtain images in the oral cavity. The field of view angle, a bright light source, and the quality of the camera one uses to obtain the image. Cameras are either a USB camera designed to clip onto the ridged scope or a camera adapter fitted to a standard digital camera that allows it to attach to the scope. Many of the digital cameras have wireless communication capa-



Fig. 1. Eezy-view camera with an image captured of a maxillary cheek tooth in a horse.

bility that allows the image viewing and capturing to be performed on a tablet device. Clients and the practitioner can use the larger screen of the tablet to view the oral cavity and even record voice descriptions of the exam. Below is an example of components to build your DIY systems.

1. Rigid endoscope with 30° to 120° field of view with a minimum length of 30 cm. The Storz Endocameleon™ is a specialized scope that has a variable viewing angle from 0° to 120°^f.
2. USB high-definition camera with capturing software or camera mount to digital camera or smart phone.
3. Endoscopic light source preferably battery-operated light-emitting diode (LED).
4. Storage device such as laptop, secure digital (SD) card, USB drive, or cloud storage.

3. Results

Commercially available systems will often have a warranty and will often provide some form of training to best use the system for your practice. These systems will range in price from inexpensive to several thousands of dollars. The image quality will have a direct correlation to cost.

Eezy-View Camera

This system has a 90° viewing angle, a rotatable joint at the viewing head so that the handle and viewing screen can remain in an upright position, LED light source, and wireless capability to multiple LCD monitors. The diameter is 10 mm with a shaft length of 43 cm. The image file size is low but is suitable for medical records and documentation. The price of the system is under \$700.00 US. Extra wireless LCD monitors are \$325.00 US. Storage of the images is to a removable SD card (Fig. 1).

Portascope Dental Stick

This system has a scope that is 6 mm in diameter and 23 cm long. There is a cord between the scope and the LCD screen. The price is advertised at



Fig. 2. Portascope Dental stick.

\$999.00 US. Image quality is good and adequate for demonstrating findings to owners. The ability to store images with this system is not known. Wifi capability can be added to this system (Fig. 2).

Stoll Oral Endoscope

This system is an excellent system for examination, demonstrating oral findings to clients, and visualizing oral surgical procedures, and produces high-quality images for recordkeeping and publishing. The system utilizes a light source that is powered by a USB port from the laptop computer. The basic components are a Storz ridged endoscope, Storz USB light source, Storz USB camera, and laptop computer. Various Storz rigid endoscopes can be utilized with the system. Price for the system is approximately \$6000.00 US without the laptop. There is an option for this system to have irrigation to rinse debris from the viewing head (Fig. 3).

Dr. Fritz Dental Stick

This wireless system has several different configurations. The endoscope viewing angle is 90° with LEDs as the light source. The focal distance tends to be close to the structure being imaged making it slightly difficult to orientate yourself in the mouth.

The image is sent wirelessly to a tablet device. The endoscope has rechargeable battery packs that

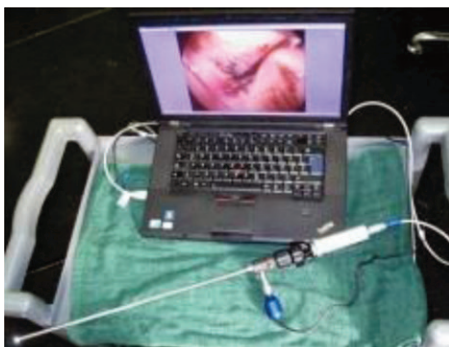


Fig. 3. Stoll Oral endoscope shown here with USB LED light source, Storz USB camera, and Storz boroscope.



Fig. 4. Dr. Fritz wireless dental stick.

are interchangeable. Storage of the images is via the tablet's storage capabilities. This system produces a nice image and is extremely portable. The cost of the system is \$6000.00 to \$8000.00 US, depending on options that one wants to purchase with the system (Fig. 4).

MDS Scope Source Flexible Video Endoscope

This is a system that utilizes a four-way directional flexible endoscope with irrigation and biopsy channel. The diameter is 8 mm and the length is 140 cm. The digital image produced is excellent for demonstrating findings to clients and for publishable-quality images. The small diameter of the scope allows the end to be bent in a close radius allowing visualization from 0° to 120°. A protective sheath of nylon is custom made and slid over the scope end to protect it from abrasive areas of the teeth. The sheath also serves as a handle and provides rigidity to the end of the scope while in the mouth. Portability is hampered; however, there are options for cases to contain the components. The system has the added advantage of being able to perform upper airway exams as well with the protective nylon sheath removed. Cost of the entire system is ~\$13,000 US (Fig. 5).

DIY-assembled systems may come with a warranty on certain components but overall the system will not be warranted. The system will also not come with training specific to the horse's mouth. The operator will have to be willing to trouble-shoot problems that arise with the system. All of the following systems described demonstrate different camera options that can be attached to a ridged endoscope. The practitioner must first purchase a rigid endoscope (Fig. 6) with specifications listed above and couple that with a camera. The Storz endocameleon has a variable viewing angle from 0° to 120° degrees (Fig. 7). Rigid scopes can range in price from used of \$1000.00 US to new prices up to

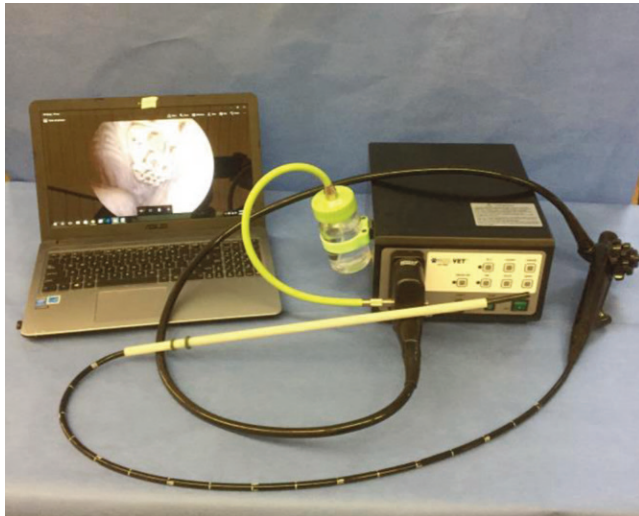


Fig. 5. MDS Scope source 8-mm flexible endoscope shown with the protective nylon sheath. This system can also be used as an upper airway system.

\$5000.00 US. Below will be combinations of DIY systems that are being used.

Smartphone DIY System

This system has a smartphone adapter that enables a smartphone to be attached directly to the rigid endoscope. A light source is also needed. The smartphone adapters are priced around \$600 to \$800 US (Fig. 8).

DIY USB Camera and Standard Digital Camera Systems

Several endoscope cameras are available that mount to the endoscope with a USB connection to a laptop (Fig. 9). Mounts can be purchased that allow digital cameras to be attached directly to the endoscope



Fig. 6. Example of rigid endoscopes (Top, 6 mm × 30 cm and bottom, 10 mm × 42 cm) both with 70° viewing angles. (Author photos.)



Fig. 7. Examples of two rigid scopes of different lengths (Top) 30° viewing angle. Bottom, Unique scope that has the capability of changing the viewing angle from 0° to 120° called the Endo-cameleon. (Courtesy of Dr. Jack Easley.)

(Fig. 10). Light sources are still needed to provide light through the fiber optics of the scope. USB cameras can range from a few hundred dollars to several thousand dollars depending on image quality.

Medical Case Selection

The cases that are especially pertinent to utilize an endoscope are patients that have small oral cavities that are difficult to inspect with a dental mirror. Patients that have progressive pathology such as periodontal disease or endodontic decay lend well to having images captured for the medical record to document progression and response to treatments. Patients with trauma or that have an extremely painful condition in the oral cavity are often best examined with an oral scope to minimize the amount of stimulation in the oral cavity with bulky instrumentation.

In the author's practice the horse is sedated, a full-mouth speculum is placed and the mouth is rinsed free of organic debris. The horse needs to be sedated to the point of minimal tongue movement. The author prefers to still utilize a mouth mirror to quickly inspect the oral cavity and then perform a detailed inspection with the oral scope. The maxillary quadrants of the teeth are inspected first visualizing each tooth in entirety looking at the surface of each pulp horn and each infundibulum (Fig. 11). The scope is rocked slightly sideways looking at the buccal and lingual surfaces for evidence of periodontal disease and cemental decay (Fig. 12). If the particular scope that is being used is 0° to 45°, the soft palate and caudal oral cavity can also be inspected for soft-tissue lesions. The mandibular quadrants are inspected in a similar manner. The tongue will often have to be gently moved toward the opposite quadrant to visualize the lingual surface and the areas under the tongue. If the horse is resistant or is having increased tongue movement lidocaine jelly or lidocaine solution can be

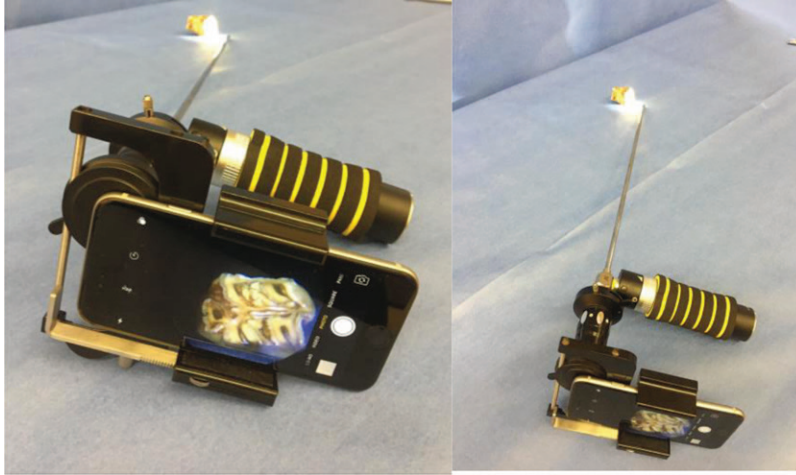


Fig. 8. Cell phone adapter case^e coupled with a 6 mm × 42 cm scope with a 70° viewing angle and battery-operated LED light source. (Author photo.)

coated on the tongue and adjacent soft tissues. Lidocaine can be sprayed in the mouth with a Luer lock syringe attached to a 20-gauge needle with the needle broken off at the hub. The lidocaine jelly can be placed on a gauze sponge and smeared on the tissues using a long alligator forceps so that your hand does not need to be placed in the mouth. The author encourages the user to purchase a scope that can focus well at several focal distances. This allows visualization of a whole tooth and part of the adjacent tooth so that you do not lose your place in the mouth. This is particularly important when examining the teeth in the center of the quadrant as the teeth all look similar and it is easy to lose your place and describe the wrong tooth.

The author utilizes Dropbox™, an online storage program that host the images locally on your computer. The file tree is created by year, month,

owner last name, and then patient name. This allows access from any computer that is online and the images are labeled by tooth inspected. Videos as well as still images are stored for use in medical records and discharge papers.

4. Discussion

The practitioner that is providing dental services is encouraged to consider adding oral endoscopy to their practice. The main reasons would include the ability to provide a more thorough examination, allow the clients to visualize the exam with the practitioner, and the ability to allow documentation of the examination for following pathologic conditions. The practitioner must choose a system that fits the needs of the practice. The considerations can be distilled down to price, portability, ease of use, and image quality.



Fig. 9. USB camera mounted on a 6 mm × 42 cm 70° viewing angle scope with a battery-powered LED light source. (Author photos.)



Fig. 10. Digital camera with wifi capability coupled to a rigid endoscope with a battery-operated LED light source. Pictured here is a Panasonic Lumix^h GF6 camera with a micro four-thirds to C-mount adapter and a C-mount coupling lens. (Courtesy of Jack Easley.)

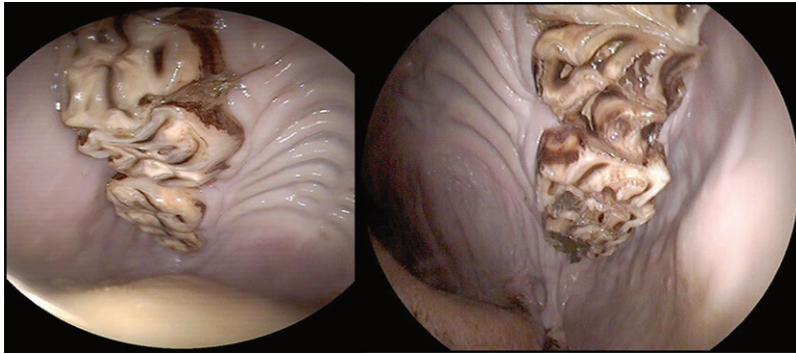


Fig. 11. Left, Axially rotated 109 with diastema at 108 and 109 tooth. Right, Complicated crown fracture tooth 109 with all pulp horns exposed.

The practitioner must first decide their budget as it is hard to effectively increase one's profit with an oral scope over proper use of a dental mirror. It however does increase one's marketing of the oral exam to the client with images and the ability to add them into the medical record. The author utilizes a flexible endoscope for in clinic procedures that stores the images automatically into a patient file that is on Dropbox™. This allows easy sharing of the images between practitioners and the safety of cloud backup. The flexible endoscope has the benefit of being able to change the angle of viewing and in patients with sinus disease, this system can be utilized to perform upper airway exams or sinoscopy. The one drawback to this system is the lack of easy transportation.

The commercially available systems that are inexpensive are good for the practitioner that wants to show clients the examination and to document pathology in the medical record. The image quality will not be of publishable quality nor do they have the ability to have irrigation. Irrigation is a must if the practitioner wants to perform endoscopic-guided intraoral surgery. In the present time, the flexible endoscope and the Stoll systems with a Storz scope and USB camera are the only ones with true irrigation capabilities.

The DIY systems are for the practitioner that has some technology in their background. One must be

careful to not spend more money piecing a system together, than if you had bought a commercially available system that would have training and a warranty.

There are several things to beware of when shopping for a system. Wireless systems are great and extremely portable. The disadvantage of some of the wireless systems can be connectivity. One should always demo a system before purchase and compare several systems. There can be a wide variety of focal distances and area of viewing that can make them hard to operate. For instance, a scope that has trouble getting a full tooth in view at a time can make it hard to keep track of which tooth you are viewing during the exam. It is better to have a scope that can focus at different lengths to be able to get an overall view of the quadrant and then move in to examine the pathologic lesion closely.

5. Conclusion

There are many options for systems to examine and document the oral examination findings. The practitioner should spend ample time and demo several systems to find the system that is right for their practice situation.

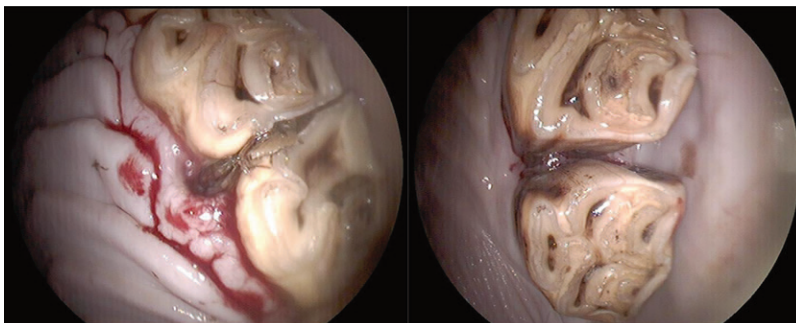


Fig. 12. Left, Senile diastema of the 208 and 209 teeth. Right, Open diastema of teeth 210 and 211.

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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^fKARL STORZ Endoscopy, Inc., 2151 E. Grand Avenue, El Segundo, CA 90245-5017.

^hPanasonic Camera, <http://shop.panasonic.com/support-only/DMC-GF6KW.html>.

Sinoscopy: How to Navigate This Complex Area

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1. Introduction

Nasal discharge is often the common clinical sign of sinus disease noted by the horse owner. Nasal discharge may be caused by both primary sinusitis (bacterial or fungal infection) or secondary sinusitis (dental disease, ethmoid hematoma, sinus cyst, neoplasia). Whatever the cause may be, the most commonly performed diagnostics are skull radiographs and nasal endoscopy. Sinoscopy is another diagnostic tool that is minimally invasive and can be performed in the standing horse by both specialists and general practitioners.¹ With a complete/accurate understanding of sinus anatomy and access to a flexible or rigid endoscope, sinoscopy can increase a practitioner's diagnostic capabilities. Furthermore, sinoscopy can be used for sample collection for histologic examination and microbial culture and a therapeutic tool for manually removing inspissated pus or foreign material from numerous sinus compartments. One study claims 69% resolution of paranasal sinus disease after sinoscopy and lavage.² More recent studies by Perkins et al^{3,4} evaluated numerous trephination sites for sinoscopy and showed that a combination approach to the sinuses via sinoscopy is very useful for diagnosis and treatment of sinus disease.

From the authors' experience, sinoscopy is extremely helpful as a diagnostic tool, but has limited value for treatment of sinus disease. Fortunately,

a sinoscopy procedure does not prevent the ability to perform additional, more invasive sinusotomy procedures when sinoscopic treatment options are unsuccessful. To most effectively use this diagnostic and therapeutic option, it is important that the practitioner understand sinoscopy capabilities and limitations. The objectives of this how-to article are 1) to describe equine sinoscopy via multiple trephination sites, and 2) describe the sinus anatomy as it pertains to sinoscopy via multiple trephination sites so that general practitioners may effectively use this diagnostic and therapeutic technique in their practice.

2. Materials and Methods

With standing sedation (alpha-2 agonist ± opiate) and local anesthesia, a small ($\frac{1}{2}$ – $\frac{3}{4}$ in.) trephine hole can be placed in the conchofrontal (CFS) or rostral (RMS) and/or caudal maxillary sinus (CMS) compartment for direct evaluation via a rigid or flexible endoscope. In prolonged procedures, a constant-rate infusion may be used as well and has been described by Vignani et al.⁵ Traditionally, the following portals have been used: for the CMS, 2 cm rostral and 2 cm ventral to the medial canthus of the eye; for the RMS, 50% of the distance from the rostral end of the facial crest to the level of the medial canthus and 1 cm ventral to a line joining the infraorbital foramen and the medial canthus;

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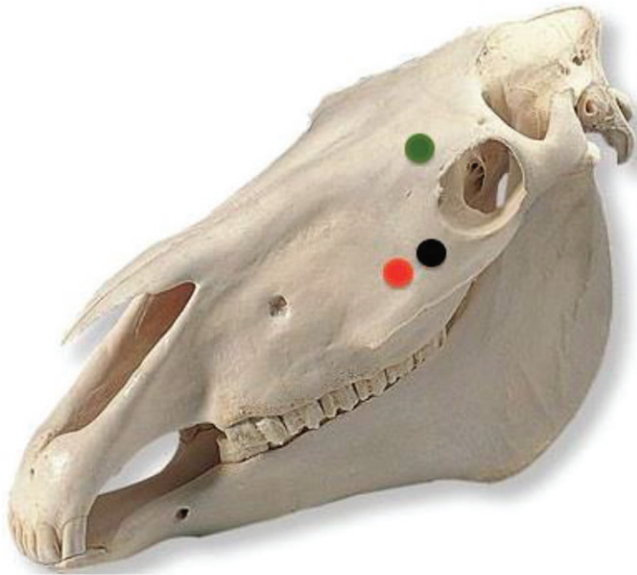


Fig. 1. Equine skull with location of common trephination sites for the frontal sinus (green circle), CMS (black circle), and RMS (red circle).

and the CFS, 60% of the distance from midline toward the medial canthus and 0.5 cm caudal to the medial canthus (Fig. 1).

The author recommends using a Galt Trephine ($\frac{1}{2}$ – $\frac{3}{4}$ in.) for sinus trephination. Once the trephination site has been located, the area should be clipped and prepped for sterile surgery. A local anesthetic is placed along the line of the proposed incision. A linear incision twice the length of the diameter of the trephine is made through the skin and the periosteum in a single incision. Alternatively, a U-shaped or semicircular incision can be created. The periosteum is elevated at the surgical site so as to preserve the periosteum during the trephination procedure. The centralized pin of the Galt Trephine is centered within the incision site and seated within the bone to hold the trephine threads in place during the procedure. It is important to perform the trephination with smooth and flat rotations of the wrist during the trephination procedure. Try to avoid “rocking” of the trephine. It is recommended to cut slowly through the bone, checking the depth frequently and leaving only a thin shell of bone that can be removed with a hemostat following the procedure. This prevents the bone fragment from falling into the sinus as well as helping to avoid any damage to sinus structures when the trephine breaks through the bone.

A rigid or flexible endoscope can be used for sinoscopy. There are advantages and disadvantages to both. A flexible endoscope is capable of flexing in multiple directions and looks directly forward (0°), which allows for improved access to numerous sinus compartments. A flexible endoscope also has a biopsy channel as well as pressurized air and water

that can be used to clear the camera when fogged or covered with blood, mucus, etc. Unfortunately, a flexible endoscope can be expensive and is at higher risk of damage when used in the sinus compartments if dragged against a rough edge creating damage to the seal of the scope. A rigid endoscope can also be used with success. Rigid scopes come in numerous angles (0° , 30° , 45° , 90°). It is recommended to use a rigid endoscope with 30° or less. Rigid endoscopy is becoming commonplace in dentistry and many of these dental oroscopes could be used successfully in sinoscopy.

Although most commonly used for diagnostic purposes, sinoscopy can be a helpful therapeutic tool as well. Both debridement and lavage of specific sinus compartments can be aided by the use of sinoscopy. Debridement can be performed through a secondary trephination hole using a series of Ferris-Smith ronguers, endoscopic grasping forceps, or curettes. In addition, if using a flexible endoscope, one may use the endoscopic biopsy forceps in conjunction with lavage through the endoscopic biopsy channel to target the removal of a specific object.

3. Results

Structures within the paranasal sinus compartments such as the infraorbital canal, frontomaxillary aperture, nasomaxillary aperture, and septum of the maxillary sinuses play a vital role in understanding surgical anatomy of the paranasal sinuses and if able to be identified, serve as landmarks for paranasal sinus surgery. When identified, these four structures will guide the surgeon throughout sinoscopic exploration. To simplify the complexity of the equine paranasal sinuses, the author likes to follow a few simple rules during surgical exploration: 1) if dorsal to the frontomaxillary aperture, the scope is within the dorsal conchal sinus or frontal sinus compartments; 2) if ventral to the frontomaxillary aperture and abaxial to infraorbital canal, the scope is within in the CMS; 3) if ventral to frontomaxillary aperture and axial to the infraorbital canal, the scope is approaching the sphenopalatine sinus compartment; 4) if caudal to the septum of the maxillary sinuses, the scope is within the CMS; 5) if rostral to the septum of the maxillary sinuses, the scope is within the RMS or ventral conchal sinus (VCS); 5) if rostral to septum of the maxillary sinuses and abaxial to infraorbital canal, the scope is within the RMS; and 6) if rostral to septum of the maxillary sinuses and axial to infraorbital canal, then the scope is within the VCS (Fig. 2, A–C).

It is important to realize that the septum of the maxillary sinuses separates the VCS and RMS from the rest of the sinus compartments. When performing sinoscopy via a CFS approach, the septum must be broken down to access the VCS and RMS (Fig. 2C). Even though the CFS approach does not directly access the VCS and RMS, it indirectly approaches both compartments via the septum. An

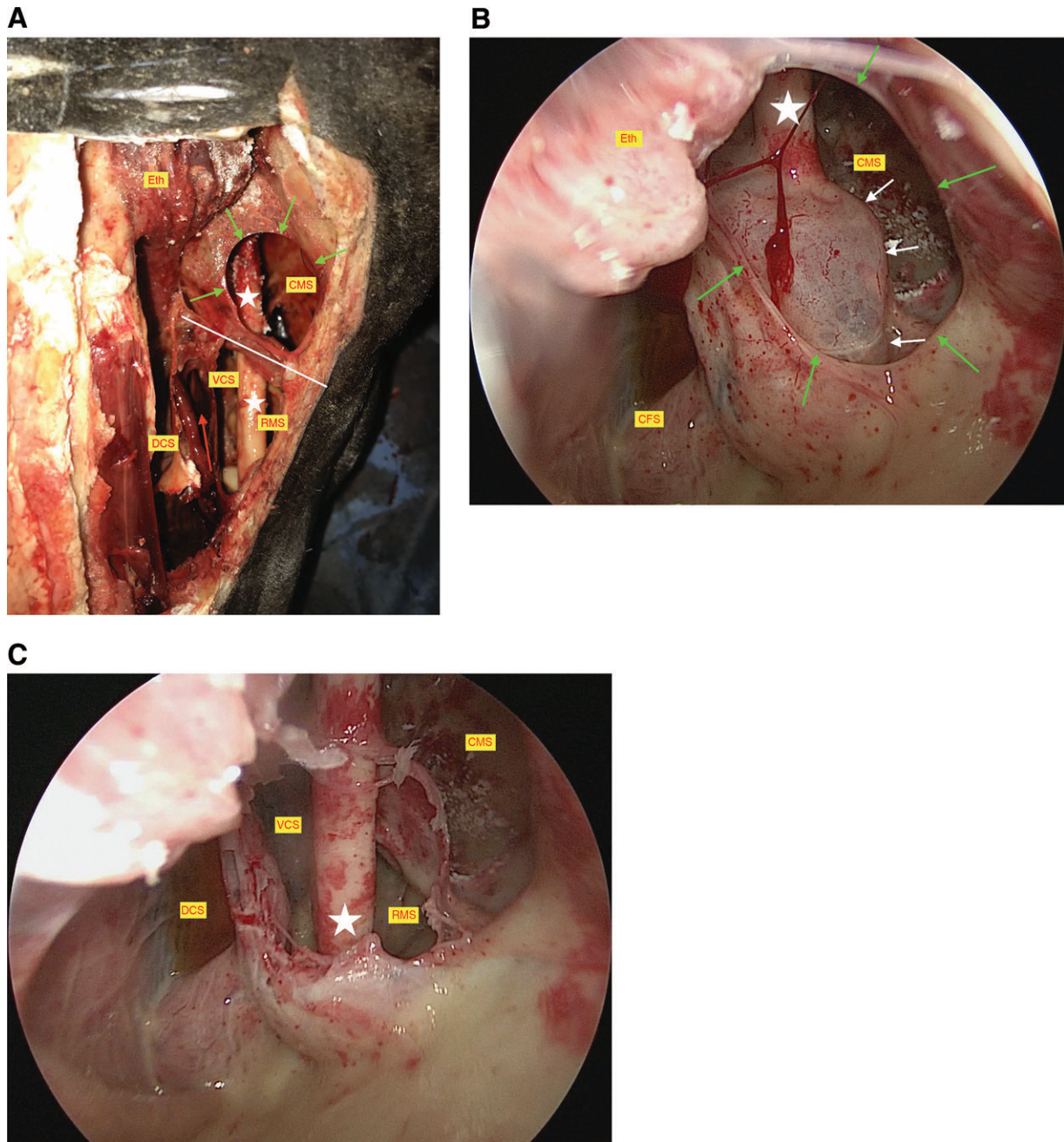


Fig. 2. A. Close-up image of the sinus compartments via a frontonasal sinus flap. Green arrows, frontomaxillary aperture; red arrow, nasomaxillary aperture (drainage of sinuses into the nasal cavity); white star, infraorbital canal as it extends through the CMS and RMS/VCS; Eth, ethmoidal sinus; CMS, caudal maxillary sinus; DCS, dorsal conchal sinus; VCS, ventral conchal sinus; RMS, rostral maxillary sinus; white line, septum of maxillary sinuses (dorsal aspect of septum) has been removed to provide access to the VCS and RMS. B. Close-up sinoscopic image via a CFS trephination looking down into the sinus compartments. Green arrows, frontomaxillary aperture; white arrows, intact septum of maxillary sinuses; white star, infraorbital canal as it extends through the CMS; Eth, ethmoidal sinus; CMS, caudal maxillary sinus; CFS, conchofrontal sinus (combination of frontal and dorsal conchal sinus compartment). C. Close-up sinoscopic image via a CFS trephination looking down into the sinus compartments after the septum of the maxillary sinuses has been broken down to provide access to the VCS and RMS. White star, infraorbital canal as it extends across the VCS and RMS (note the separation of the VCS from the RMS by the infraorbital canal); DCS, dorsal conchal sinus; CMS, caudal maxillary sinus; VCS, ventral conchal sinus; RMS, rostral maxillary sinus.

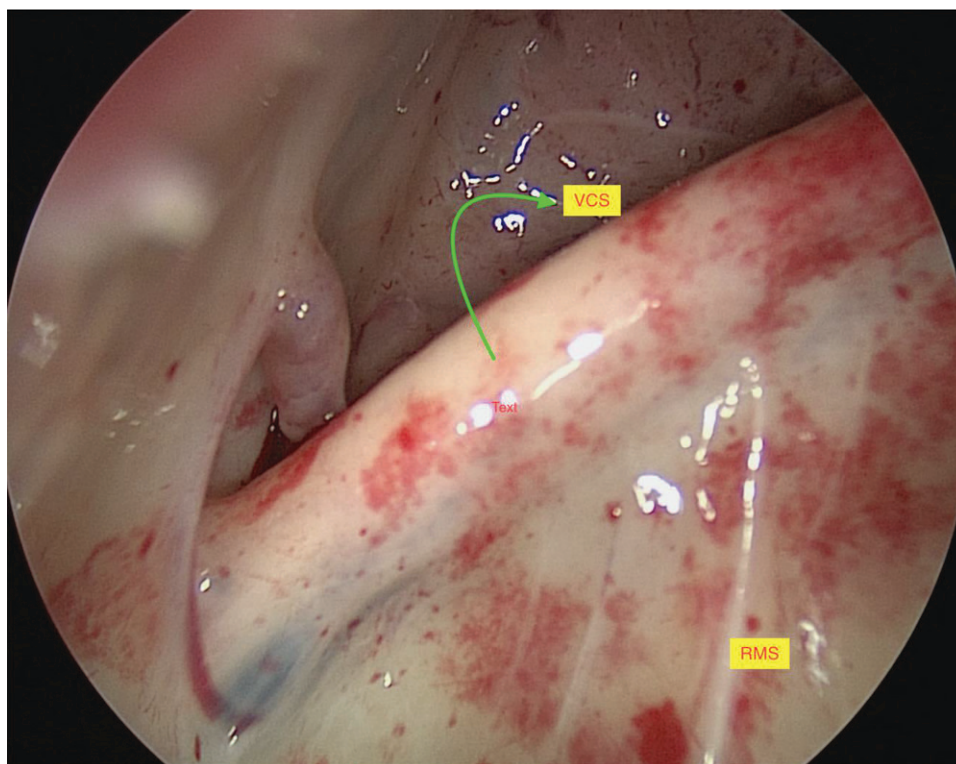


Fig. 3. Close-up sinoscopic image via an RMS trephination. Note the small size of the sinus compartments via this approach. The RMS approach provides direct access to the RMS, but the infraorbital canal limits access to the VCS. Green arrow, direction of endoscope over top of the infraorbital canal to access the VCS, which is not easily performed; VCS, ventral conchal sinus; RMS, rostral maxillary sinus.

RMS approach may seem to be the most direct approach to the VCS and RMS. Unfortunately, the RMS and VCS are small compartments providing only limited access and making it nearly impossible to access the VCS directly because the infraorbital canal blocks direct access via the RMS approach (Fig. 3).

4. Discussion

Sinoscopy as both a diagnostic and therapeutic tool can be performed easily in the standing, sedated horse by surgeons and general practitioners. Accurate anatomical understanding of normal sinus compartments is vital to sinoscopic success. As the horse ages and the maxillary teeth erupt further into the mouth, the teeth take up less space within the sinus compartments and compartments enlarge. This makes sinoscopy in an older horse easier and more rewarding. Sinus disease can distort sinus anatomy making sinoscopy confusing or challenging in certain scenarios. However, if the practitioner identifies the appropriate “normal” location of the important landmarks used for sinoscopy, diagnosis and therapy can often be achieved.

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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How to Perform Gastroscope and Diagnose Pathology of the Upper Gastrointestinal Tract

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1. Introduction

Evaluation of the gastrointestinal (GI) tract should be undertaken to evaluate a horse for pathology of the esophagus, non-glandular mucosa of the stomach, glandular mucosa and pylorus of the stomach, and proximal duodenum.

2. Materials and Methods

Equipment Preparation

For a gastroscope, a 3-m scope is preferred. In some smaller horses or foals a shorter scope may allow some visualization. In very large horses, a 3-m scope may not be able to examine the duodenum. A short investment of time in preparation of the equipment can save valuable time during the exam. Prior to the examination, the scope should be confirmed to be working, the biopsy channel should be clear, the water channel should be functioning and pushing water across the lens. The author uses additional equipment for rapid insufflation of the stomach and for a more powerful water jet both via the biopsy channel. The scope should articulate in all four directions. If image capture is desired, the equipment should be turned on and the patient information programmed into the correct fields.

Patient Preparation

Once the equipment is set up correctly, the patient should be prepared for endoscopy. A minimum of 12 hours and the author prefers 18 hours of fasting from hay and feed should have been performed. A minimum of 6 hours of fasting from water should have been performed. For patients being seen on the farm or as outpatients, it is very important to discuss fasting and muzzling with the owners. Additionally, the transport must know not to allow any access to hay on the trailer or grass prior to endoscopy.

The patient should be restrained in a manner comfortable for the veterinarian and veterinary staff. The author sedates all gastroscope cases and examines the majority in stocks. Any sedation that the veterinarian is comfortable with is appropriate if the depth of sedation is deep enough to allow safe passage of the endoscope. Deep sedation may impact swallowing and make gastroscope more difficult. The author prefers romifidine at 0.04 to 0.05 mg/kg. Occasionally a nose twitch or additional device may be necessary to allow safe passage of the endoscope after sedation.

Passage of the Endoscope

A lubricated scope is introduced into one nostril and passed to the pharynx. It is then passed into the

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esophagus as the patient attempts to swallow. Occasionally stimulation of the swallowing reflex needs to be induced by application of water onto the mucosa via the endoscope. If the scope is not stiff, an external tube can be used as a guide through the pharynx. Care should be taken when introducing the scope to not allow it to retroflex into the oral cavity where it can be damaged. The author will frequently lock the scope to prevent retroflexion. Alternatively, you can use a dental speculum opened slightly to prevent damage to the endoscope in case of a retroflexion.

Once in the esophagus, additional lubrication can be applied to the scope. This helps to limit any trauma to the nasal mucosa. The scope is passed quickly down the esophagus and into the stomach. Once past the cardia, the stomach should be insufflated. The author has found external air compressors such as those used for mattress to be an ideal tool to quickly insufflate the stomach. Watch the folds in the glandular mucosa as a rough gauge of gastric distension. If they are flattening out, the stomach is nearing maximum dilation.

Examination of the Stomach

Once the stomach is distended, a global view of the stomach is taken. Are there parasites on the mucosa? Is there a food bolus or mass visible? From the cardia, the scope should be directed (make sure the locks are now off) down toward the margo plicatus (MP). As you advance the scope it will wrap around the stomach. Many times, it will want to spiral up into the saccus caecus before spiraling back down toward the glandular mucosa. If you try to keep the image on the screen to be just on the glandular side of the MP this spiraling can be avoided. The initial area of the MP seen as you enter the stomach is the greater curvature. As you follow along the MP you will visualize the scope coming out of the esophagus and the lesser curvature. The scope is then directed below the lesser curvature and into the pylorus. Occasionally this requires going into gastric fluid and losing any diagnostic image for a short period. Occasionally some air must be introduced to the pylorus to distend it for evaluation. The scope should be advanced into the antrum to allow for a view of the glandular mucosa. Peristalsis is noted as the pyloric sphincter opens and closes. Occasionally bile is seen refluxing back into the stomach. The peristalsis will frequently propel the scope deeper into the pylorus and toward the pyloric sphincter. If the peristalsis does not propel the scope, retracting on the scope frequently will. When the scope is in the pylorus, it has effectively made a C shape and pulling out will move the camera deeper into the pylorus.

Examination of the Pylorus

As the scope approaches the pyloric sphincter, a 90° turn must be executed to get into the duodenum. This is done by both directing the scope with the

control knobs, and by rotating the handle of the scope externally. Both motions will change the direction of the scope tip and allow for introduction into the duodenum. Once in the duodenum some adjustments are necessary to visualize the lumen. The major duodenal papilla can be visualized and bile secretions should be seen as the duct contracts.

Examination of the Esophagus

Once the examination of the stomach and duodenum is complete, the scope should be retracted to the cardia. If the stomach is still distended some air can be removed. This is not always necessary. The scope is then retracted slowly and deliberately up the esophagus while also distending with air. This distal esophagus should be evaluated carefully for signs of acid reflux. The remainder of the esophagus is examined for damage to the mucosa.

Scoring of the Examination

Veterinarians should adopt the 0 to 4 scoring system of the Equine Gastric Ulcer Council for non-glandular ulcers.^{1,2} It is the only scoring system that has shown repeatability and correlation between examiners.³

Score	Squamous Mucosa
0	Epithelium is intact and there is no appearance of hyperkeratosis
1	The mucosa is intact but there are areas of hyperkeratosis
2	Small single or multifocal ulcers
3	Large single or extensive superficial lesions
4	Extensive lesions with areas of deep ulceration

There is no current scoring system for glandular ulcers or esophageal damage and lesions found in these areas should be described based on numbers, size, shape, and location.

3. Results

The author estimates close to 500 gastroscopies performed. One horse developed colic post gastroscopy from air distension. This horse had a pyloric stenosis and the patient became visually bloated during the examination. The occasional horse will develop bleeding from the nasal mucosa caused by trauma from the scope in the nasal passage.

With practice the procedure can be completed in 10 minutes and will require the assistance of 1 technician.

4. Discussion

Gastroscopy is performed for many different reasons. The most common is to try and determine the source of abdominal pain. Additional reasons to consider gastroscopy include poor performance, poor appetite, and abnormal or bizarre behavior. In the anorexic horse the classic history is a horse that will eat hay and either not eat grain or eat the grain very slowly. A feed/fast model is a very common way to induce gastric ulcers experimentally and cause or

effect should be considered when examining ulcers in anorexic horses. Horses that have been held off feed, or are anorexic for other gastrointestinal reasons will have gastric ulcers.

Occasionally masses are noted in the stomach. The author has not obtained a diagnostic sample using a small endoscopic biopsy via the biopsy channel. If a biopsy is needed, one should consider a polypectomy snare.⁴

Gastric ulcers are common in multiple populations of horses. The following populations have been examined and reported: racing Thoroughbreds (TB) (88.3%), pastured TB broodmares (70.9%), racing Standardbreds (STB) (88%), show horses (58%), endurance horses (67%), horses with abdominal pain (49%).⁵⁻¹⁰ Understanding how to efficiently perform a gastroscopy will allow for identification of the ulcers and follow up of treatment.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

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How to Overcome Clinical Challenges in an Embryo Transfer Program

Ryan A. Ferris, DVM, MS, DACT*; and Patrick M. McCue, DVM, PhD, DACT

Embryo recovery rate and recipient pregnancy rate are similar between Hartmann's solution and a complete flush solution. Pregnancy rates at 14 and 25 days were comparable for recipient mares with natural ovulations, hormonal treatment, or hormone treatment plus a natural ovulation. Ovulation without subsequent corpus luteum formation occasionally occurs. Authors' address: Equine Reproduction Laboratory, Department of Clinical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: rferris@colostate.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Embryo transfer is a routine procedure performed in equine practice. Embryo transfer is typically performed to obtain more than one foal per year, to attain pregnancies from older mares that are unable to carry a foal to term, to acquire a foal from mares with fertility issues, or to obtain pregnancies from mares in athletic performance.¹⁻³ The basic mechanisms of equine embryo transfer are well described; however, modifications may be required to overcome challenges in a clinical embryo transfer program. Three of the many issues in equine embryo transfer are 1) What media to use for embryo recovery? 2) What options are available if a cycling recipient is not able available for a donor? and 3) Does every recipient that ovulates have adequate progesterone to support pregnancy?

The options for embryo recovery fluid can be overwhelming. It is common in the United States to perform embryo-recovery attempts with a commercially manufactured media that includes a Zwitterion-based buffer, antibiotics, and a surfactant (bovine serum albumin or polyvinyl alcohol).^{2,4}

In many other countries, it is common to use a crystalloid isotonic intravenous fluid (for example, lactated Ringer's solution [LRS]) with or without a surfactant. Lactated Ringer's solution is used extensively for embryo recovery in Argentina and Brazil with reported good embryo recovery and pregnancy rates. However, there has not been a direct head-to-head comparison for embryo recovery between a complete flush media and a crystalloid isotonic fluid.

One of the more important factors affecting the likelihood of establishing a pregnancy after embryo transfer is donor-recipient synchrony. Several studies have suggested that adequate pregnancy rates can be achieved when recipients ovulate 1 day before the donor (+1) or up to 3 days after the donor (-3).^{5,6} A common issue in an embryo-transfer program is having a large-enough pool of cycling recipients early in the season to match the embryo-donor population. When a cycling recipient is unavailable to match up with a donor mare, an option is to administer estrogen for 2 days followed by progesterone for 5 days to transitional or anestrus recipient mares.⁷⁻¹¹ This hormone-treatment

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protocol mimics the normal increase in estrogen prior to ovulation and the progesterone-dominated phase following ovulation that occurs in a normal-cycling mare. Various groups have used these protocols with success ranging from 40% to 76%.^{7,9-11}

When an embryo-transfer recipient ovulates, or is started on exogenous progesterone therapy there is a presumption that progesterone values 5 days later will be greater than 4 ng/mL. Progesterone is responsible for increased uterine and cervical tone found in an ideal embryo-transfer recipient mare. Low progesterone levels are associated with decreased cervical and uterine tone.¹² The minimum level of progesterone capable of supporting a pregnancy has been reported to be approximately 2.5 ng/mL.⁸

The objectives of this study were to 1) compare embryo recovery rates and pregnancy rates in recipients at 14 and 25 days (embryo age) between complete flush solution and Hartmann's solution; 2) evaluate pregnancy rates in recipients with a natural ovulation, hormone treatment, or both a natural ovulation and hormone treatment; and 3) determine progesterone values 5 days post ovulation.

2. Materials and Methods

Study 1

Embryo recovery was performed on day 7 or 8 after ovulation. An 8-mm internal diameter sterile silicone catheter with an inflatable cuff was advanced through the cervix, and the cuff was inflated with air and pulled against the internal cervical os. The catheter was attached to sterile Y-tubing that connected the catheter to the fluid bag and a 75- μ m embryo filter. Embryo-recovery procedures were performed using either complete flush media^a or Hartmann's solution^b on an alternating basis (i.e., every other mare) throughout the 2016 breeding season. The filter was rinsed with complete flush media following embryo-recovery media regardless of whether complete flush media or Hartmann's solution was used. For data analysis, each embryo-recovery attempt was treated as a positive or negative event, irrespective of the number of ovulations or embryos recovered. Embryos were transferred by one of two experienced clinicians into recipient mares, all mares were maintained on altrenogest starting at the time of transfer through 120 days of pregnancy. Pregnancy exams were performed at days 14 and 25 (embryo age).

Study 2

Once a donor mare ovulated, a recipient mare was synchronized using one of the three following treatments, 1) natural ovulation: a recipient mare with >35-mm follicle with uterine edema present was administered a gonadotropin-releasing hormone (GnRH) agonist or human chorionic gonadotropin to induce ovulation, 2) hormone treated: a transitional or anestrus mare was administered estrogen

(6.6 mg IM) on 2 consecutive days followed by 5 to 7 days of short-acting progesterone (200 mg IM), 3) natural ovulation plus hormone treatment: if a recipient mare failed to respond to a GnRH agonist within 48 hours, the mare was administered human chorionic gonadotropin (hCG) plus short-acting progesterone (200 mg IM) on the same day with short-acting progesterone therapy continuing for 5 to 7 days. The natural-ovulation-plus-hormone-treatment group included some cycling mares that were in early estrus but did not have a follicle that could be induced with a GnRH agonist or hCG. The ultimate goal for all the treatment groups was to have recipient mares exposed to estrogen for at least 2 days followed by 5 to 7 days of progesterone exposure prior to receiving an embryo.

Study 3

A blood sample was collected in an ethylenediaminetetraacetic acid (EDTA) vacuum tube for every recipient mare 5 days after ovulation. Progesterone concentration was determined using an enzyme-linked fluorescent assay (ELFA).

Data are presented as mean \pm standard deviation. Statistical analysis for categorical data was compared using χ^2 analysis, continuous data was compared using a Student *t* test. A significant difference was considered if a $P < .05$ was detected.

3. Results

Study 1

A total of 78 embryo-recovery attempts were performed with complete flush solution and 77 were performed with Hartmann's solution. There was no statistical difference ($P = .19$) in the percentage of positive embryo recovery attempts when comparing complete flush media (46.2%; 36 of 78) and Hartmann's solution (57.1%; 44 of 77; Fig. 1). When recovery of twin embryos were included, a total of 41 embryos were recovered using complete flush media and 47 embryos were recovered with Hartmann's solution. There was no significant difference in pregnancy rates in recipient mares for embryos recovered in complete flush media or Hartmann's solution at 14 days (80.5%, 33 of 41; vs 80.8%, 38 of 47, respectively) or 25 days (78.0%, 32 of 41; vs 76.6%, 36 of 47, respectively) of embryo age (Fig. 1).

Study 2

A total of 118 *in vivo* produced fresh or cool-shipped embryos were transferred, with 14- and 25-day pregnancy rates of 80% and 76%, respectively. Sixty-five embryos were transferred into recipients with natural ovulations, resulting in a 14- and 25-day pregnancy rates of 75% and 69%, respectively (Fig. 2). For recipients that were hormone treated, 40 embryos were transferred with 14- and 25-day pregnancy rates of 85% and 83%, respectively (Fig. 2). Fourteen embryos were transferred into recipient mares with a natural ovulation plus hormone

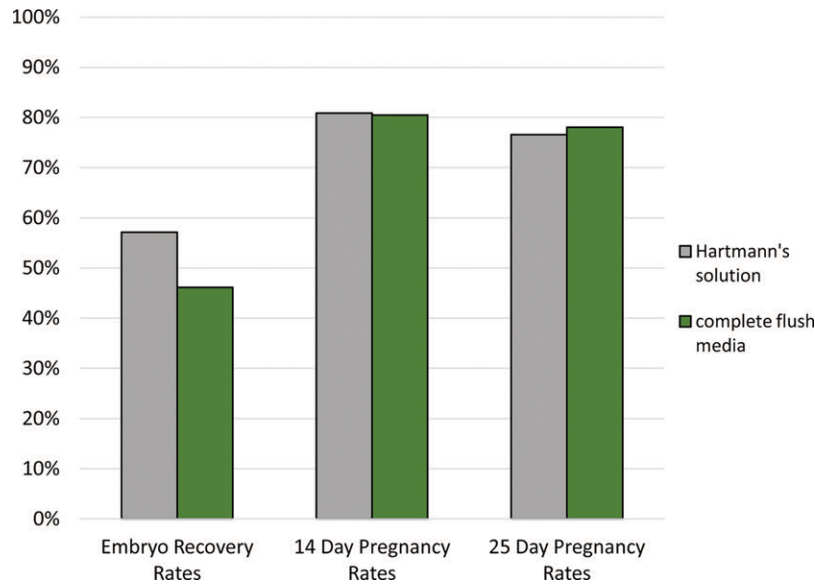


Fig. 1. Embryo recovery and pregnancy rates following embryo transfer with complete flush media or Hartmann's solution. There were no significant differences in either embryo recovery or pregnancy rates ($P > .05$).

therapy with 14 and 25 day pregnancy rates of 86% and 86%, respectively (Fig. 2). There were no significant differences observed in pregnancy rates between recipients with natural ovulations, hormone therapy, or natural ovulation plus hormone therapy.

Study 3

A total of 218 recipient cycles were evaluated 5 days after ovulation for progesterone concentration with a natural ovulation. The mean progesterone value 5 days after ovulation was 9.4 ± 3.7 ng/mL (Table 1). In recipient mares with natural ovulations, 5.5% of mares (12 of 218) were found to have a progesterone value of <4.0 ng/mL and 0.9% of mares (2 of 218) had progesterone values of <1.0 ng/mL (Table 1).

4. Discussion

Previous studies have reported good embryo-recovery rates using an isotonic crystalloid fluid (i.e., LRS)¹³ To the authors' knowledge, there has not been a direct comparison of embryo-recovery rates at the same facility using commercial complete-flush media or a crystalloid fluid. In the current study, no difference in embryo recovery was observed between a commercial complete-flush media and Hartmann's solution. The use of a surfactant has been suggested for crystalloid fluids due to the possibility of an embryo sticking to the catheter, tubing, cup, or search dish in the embryo-recovery process.^{1,2} However, based on the results of the current study using a

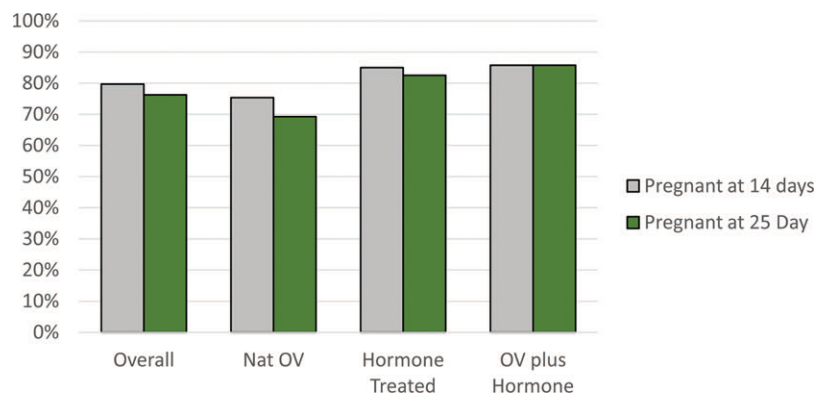


Fig. 2. Pregnancy rates in recipients with natural ovulations (Nat OV), 2 days of estrogen and 5 to 7 days of progesterone therapy (Hormone Treated), and mares with a natural ovulation plus hormone treatment (OV plus Hormone) at 14 and 25 days of embryo age. There were no significant differences in embryo recovery or pregnancy rates ($P > .05$).

Table 1. Progesterone Values Measured in Recipient Mares 5 Days Post Ovulation or After 5 Days of Exogenous Progesterone Therapy

	Natural Ovulations
Mean progesterone value	9.4 ± 3.7 ng/mL (n = 218)
Incidence <4.0 ng/mL	5.5% (12 of 218)
Incidence <1.0 ng/mL	0.9% (2 of 218)

nonsurfactant media there was no decrease in embryo-recovery rates.

In the current study the filter was rinsed using a surfactant-containing media, complete-flush solution, to minimize the chance of an embryo sticking to the plastic search dish. The authors elected to use a surfactant-containing media to rinse the filter as preliminary evaluation of Hartmann's solution resulted in one embryo sticking to the bottom of the embryo search dish. This embryo was gently lifted off the bottom of the dish, washed, and transferred, which subsequently resulted in a pregnancy in the recipient mare.

Historically, studies in which embryos were transferred into noncycling or ovariectomized recipient mares had low sample size.^{8,14,15} Recently, several studies with more than 40 embryos transferred found no difference in pregnancy rates between hormone-treated acyclic recipients and cycling recipient mares.⁹⁻¹¹ The current study also found no difference between hormone-treated noncycling recipients and recipient mares with a natural ovulation. Estrogen followed by progesterone administration to acyclic mares can result in a pregnancy rate similar to that associated with a natural ovulation.

Unfortunately, mares do not always ovulate after administration of an ovulation-induction agent. Recipient mares with a follicle >35 mm are typically administered a GnRH agonist on the day a donor mare ovulates. In the current study, if a recipient mare failed to ovulate, in response to a GnRH agonist, the mare was started on 200 mg of progesterone plus administered hCG in an attempt to induce ovulation. Injectable progesterone therapy was continued until either an embryo was transferred or until the recipient was no longer in synchrony with a donor. The goal of this treatment was to create a recipient with a progesterone-dominated period for 5 to 7 days prior to receiving an embryo. This management scheme of hormone treatment plus ovulation induction is advantageous when there are limited numbers of recipient mares available and allows for a greater efficiency in recipient management.

Hormone therapy was also used in cycling recipients that were in early estrus (minimal to no uterine edema and <30 mm follicle) in which mares were treated for 2 days with injectable estrogen followed by injectable progesterone administration. Often when injectable progesterone was ready to be started the recipient would have a follicle >35 mm

and ovulation could be induced. This situation was used on four recipient mares in the current study late in the breeding season, to match up large embryo donors with appropriately sized recipients. The use of hormone therapy in cycling mares in early estrus can help practitioners match up specific recipients with donor mares; this protocol may be especially helpful in situations where a client has one donor and only one recipient mare.

Clinicians often assume that when a mare ovulates, a normal corpus luteum will form and adequate progesterone will be produced. A previous study found 3.7% (9 of 242) of the cycles had progesterone values <4.0 ng/mL at 5 days after ovulation.¹² In the current study, 5% of cycles in which an ovulation was detected had plasma progesterone values <4.0 ng/mL and 0.9% of cycles had progesterone concentrations of <1.0 ng/mL. These studies suggest that a low percentage of cycles are associated with a dysfunctional corpus luteum. In the current study a rapid-validated progesterone assay was used and none of the mares with progesterone values <4.0 ng/mL received an embryo.

4. Conclusions

Clinicians have many options for embryo-recovery fluid, with both commercial complete-flush media and Hartmann's solution having similar embryo-recovery rates and pregnancy rates in recipient mares. When cycling-recipient mares are in short supply, hormone therapy can be used in both acyclic and cycling recipients to prepare the uterus for an embryo with good pregnancy rates. Clinicians should be aware that even when an ovulation is detected, not every developing corpus luteum will secrete an adequate amount of progesterone (i.e., >4.0 ng/mL). These techniques can allow clinicians greater flexibility to overcome common challenges in embryo recovery and recipient-mare management.

Acknowledgments

The Authors declare no financial support for this project, this study is a retrospective report of clinical data generated in our program.

IACUC approval: The study performed is a retrospective report of clinical data generated in our program. An IACUC approval for client procedures is not required for retrospective studies.

Declaration of compounded medications: Compounded medications were used in this study. Veterinarians should remember that compounded drugs have not been evaluated by the FDA approval process for safety, efficacy, stability, potency, and consistency of manufacturing. One should not assume compounded drugs are consistent from one batch to another, contain the stated amount of drug substance or the desired drug substance.

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.

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^aViGRO Complete Flush Solution, Vetoquinol, Fort Worth, TX 76137.

^bVetivex®-11 Hartmann's solution, Dechra, Overland Park, KS 66211.

Effects of Urine Contamination on Semen Freezing Ability of Stallions

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Although ejaculates with low levels of urine contamination had minimal reduction in semen parameters, those with high levels of contamination had marked decreases in sperm parameters and are not suitable for cryopreservation. Authors' addresses: Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois–Urbana Champaign, Urbana, IL 61802 (Canisso, Curcio, Ellerbrock, Honorato, Lima, Massey, Rothrock, Stewart); and Department of Large Animal Clinical Sciences, College of Veterinary Medicine, Texas A&M University, College Station, TX 77843 (Love); e-mail: canisso@illinois.edu. *Correspondent author; †presenting author. © 2017 AAEP.

1. Introduction

Although current recommendations suggest urine contaminated ejaculates should not be used for cryopreservation, sometimes only contaminated samples can be obtained. The aim of this study was to determine effects of urine contamination on semen cryopreservation.

2. Materials and Methods

Forty ejaculates from eight stallions were divided into no urine (CONT), low (20% urine [LOW]), and high (50% urine [HIGH]) samples. Semen was subsequently extended,^a cushion centrifuged (1000× *g*, 20 min),^b resuspended to 200 million/mL,^c and cryopreserved. Total motility (%TM) and progressive motility (%PM) were assessed pre- and post-freezing.^d Viability, acrosome integrity, mitochondrial potential,

and sperm chromatin stability were assessed via flow cytometry. Statistical analyses performed with ANOVA (one-way, repeated measures) and Tukey's post hoc.^e

3. Results and Discussion

There was a significant reduction in %TM and %PM with increase in urine contamination pre-freezing (%TM, 67.0 ± 1.7; %PM, 49.8 ± 2.2; CONT), (%TM, 60.3 ± 1.7; %PM, 42.5 ± 2.1; LOW), and (%TM, 41.3 ± 2.0; %PM, 21.3 ± 1.5; HIGH). Post-thaw motilities CONT (%TM, 53.9 ± 2.3; %PM, 40.8 ± 3.3) and LOW (%TM, 51.7 ± 1.8; %PM, 36.2 ± 2.1) were not different, but were higher than the HIGH (%TM, 31.49 ± 1.2; %PM, 17.1 ± 1.0) (*P* < .05). Post-thaw sperm viability was significantly lower in

Research Abstract—for more information, contact the corresponding author

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the HIGH (54.7 ± 2.4) than in the CONT (63.8 ± 2.3) or LOW (64.6 ± 3.4) groups. No differences were seen in acrosome integrity or sperm chromatin stability between groups. Semen contaminated with a small amount of urine may be suitable for cryopreservation, whereas highly contaminated semen is not usable.

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.

Footnotes

^aEqui-Pro® Cool Guard®, MOFA Global, Vernon, WI 53593.

^bMaxifreeze®, IMV, Maple Grove, MN 55369.

^cBotuCrio®, Botupharma, Botucatu, Sao Paulo, Brazil.

^dSpermvision II®, MOFA Global, Verona, WI, 53593.

^eR version 3.2.2, available at: (www.r-project.org/).

The Effect of Collection Schedule on Pregnancy Rates in Mares: A Meta-Analysis

Elizabeth S. Metcalf, MS, DVM, DACT

Pregnancy rates are increased when semen is available on a daily basis; however, shipped semen is associated with lower pregnancy rates than on-farm insemination. Author's address: Honahlee PC, Sherwood, OR 97140; Andrology Division, Department of Obstetrics & Gynecology, Oregon Health & Science University School of Medicine, Portland, OR 97239; e-mail: honahlee@imagina.com. © 2017 AAEP.

1. Introduction

Availability of semen from many stallions is limited to collection every 48 hours. Pregnancy rates have been reported to be lower in mares bred with shipped semen (SS) vs on-farm insemination (OF) under this schedule.¹ This study compares pregnancy rates in mares bred OF or SS, when fresh semen is available every day vs every other day.

2. Materials and Methods

Semen containing ≥ 500 million motile spermatozoa from four proven stallions was used to inseminate mares in heat with SS over 344 cycles and mares residing OF over 73 cycles. OF mares in estrus were examined daily by transrectal ultrasound, underwent ovulation induction when a dominant follicle was >35 mm and endometrial edema was visualized, and inseminated 24 to 28 hours later. Pregnancy was documented by embryo recovery or ultrasonographic examination 14 to 18 days postovulation. The χ^2 test was used for statistical analysis.

3. Results

OF mares had higher ($P < .05$) per-cycle pregnancy rates than SS mares (75% vs 63%, respectively)

when semen was available on a daily basis for collection. When stallions are available for daily collection, pregnancy rates are higher ($P < .05$) for mares both on farm and receiving SS than pregnancy reported for every-other-day availability of semen collection (75% vs 68% and 63 vs 50%, respectively).

4. Discussion

Pregnancy rates are optimized when semen is available on a daily basis.

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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Review of Ovarian Abnormalities in the Mare: A Video Perspective

Patrick M. McCue, DVM, PhD, DACT*; and Ryan A. Ferris, DVM, MS, DACT

A majority of ovarian abnormalities can be diagnosed by transrectal ultrasonography. In some clinical cases, additional diagnostic tests such as hormone analysis or a karyotype may be indicated. Authors' address: Equine Reproduction Laboratory, Department of Clinical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: pmccue@colostate.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Evaluation of the reproductive tract of mares is a routine part of equine veterinary practice. Understanding normal and abnormal conditions of the ovary is critical for making informed decisions regarding reproductive management of mares. The goal of this written review is to describe common and less common equine ovarian abnormalities (Table 1); ultrasound videos of each abnormality will be presented at the annual convention. Transrectal ultrasonography can be used to diagnose a majority of ovarian issues.¹ Additional diagnostic tests often include reproductive history, physical examination, and hormone analysis; occasionally an ovarian biopsy or a karyotype may be important to confirm a diagnosis.

2. Anovulatory Follicles

Approximately 4% to 8% of large dominant follicles in a mare in estrus fail to ovulate during the physiologic breeding season in mares. A majority of anovulatory follicles (85%) become hemorrhagic and eventually luteinize, whereas approximately 15% of anovulatory follicles do not become hemorrhagic and remain as persistent anovulatory follicles.^{2,3}

Persistent Anovulatory Follicles

Persistent anovulatory follicles are not associated with significant hemorrhage or luteinization and serum progesterone levels are <1.0 ng/mL. Persistent anovulatory follicles are recognized on ultrasonographic examination as large static follicular structures with few to no echogenic particles or strands within the lumen (Fig. 1). Persistent anovulatory follicles are often slow to regress and may remain for weeks. Affected mares go out of heat and endometrial edema declines as estradiol levels decrease. Nonluteinized anovulatory follicles eventually regress or undergo atresia and are eventually replaced by another dominant follicle.

Luteinized Anovulatory Follicles

The fate of a dominant follicle of a mare in estrus that fails to ovulate is usually formation of a transient luteal structure. Approximately 85% of anovulatory follicles are associated with hemorrhage into the follicular lumen (i.e., a hemorrhagic anovulatory follicle) initially recognized by the presence of echogenic particles within the follicular lumen (Fig. 2). These echogenic spots are likely clumps of red blood cells, fibrin, or clusters of granulosa cells.

NOTES

Table 1. Ovarian Abnormalities in the Mare

Common Ovarian Problems	Less Common Ovarian Problems
Anovulatory follicles	Ovarian tumors
Persistent anovulatory follicles	Ovarian hematoma
Luteinized anovulatory follicles	Failure of follicular development
Persistent corpus luteum	Ovarian senescence
Premature luteolysis	Post-partum anestrus
Parovarian cysts	Exogenous hormone therapy
	GnRH vaccination
	Luteal insufficiency
	Epithelial inclusion (fossa) cysts
	Chromosomal abnormalities

Occasionally, a large amount of unclotted blood is noted swirling around during manipulation of the anovulatory follicle (Fig. 3). The delay in clotting is presumably due to the presence of anticoagulants in equine follicular fluid.

A progressive development of echogenic fibrin strands (Fig. 4) occurs over the next 2 to 3 days with eventual complete infiltration of echogenic luteinized cells (Fig. 5). Progesterone levels begin to increase within 1 to 2 days after initial detection of echogenic particles in the follicular lumen and commonly increase to greater than 8 to 10 ng/mL. Administration of a single dose of prostaglandins will usually result in complete regression of the luteinized structure, and seems to be best performed at least 9 days after initial detection of echogenic particles.

2. Persistent Corpus Luteum

A corpus luteum that fails to regress within 14 to 16 days after ovulation in a nonpregnant mare is considered to be pathologically persistent. The most commonly recognized causes of a persistent corpus

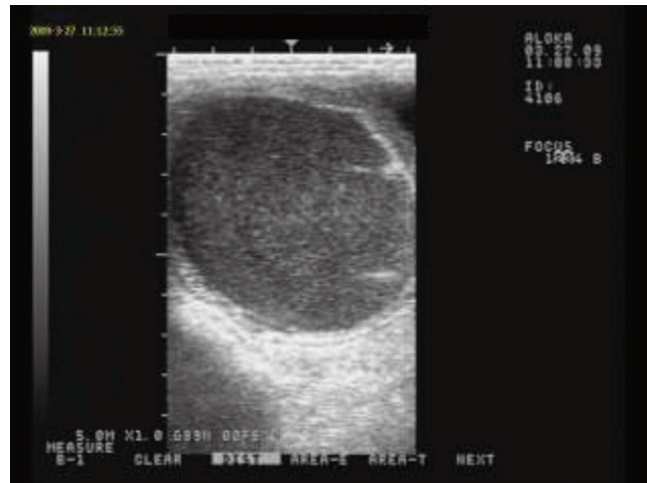


Fig. 2. Ultrasound image of initial development of a luteinized anovulatory follicle. Note the echogenic particles within the follicular lumen.

luteum are ovulations late in diestrus, embryonic loss after the time of maternal recognition of pregnancy, and chronic uterine infections (i.e., pyometra). Insertion of a sterile glass ball (i.e., marble) into the uterus, administration of oxytocin during mid-diestrus, and ovulation during a course of altrenogest therapy can also cause persistence of the corpus luteum.⁴⁻⁷ In addition, failure of the endometrium of a nonpregnant mare to secrete prostaglandins during the normal period of maternal recognition of pregnancy may also result in a persistent corpus luteum.⁸

A persistent corpus luteum is indistinguishable on ultrasonographic examination from a normal mature corpus luteum (Fig. 6). Mares with a persistent corpus luteum will have good tone in the uterus and cervix, a pale, tight and dry cervix on speculum

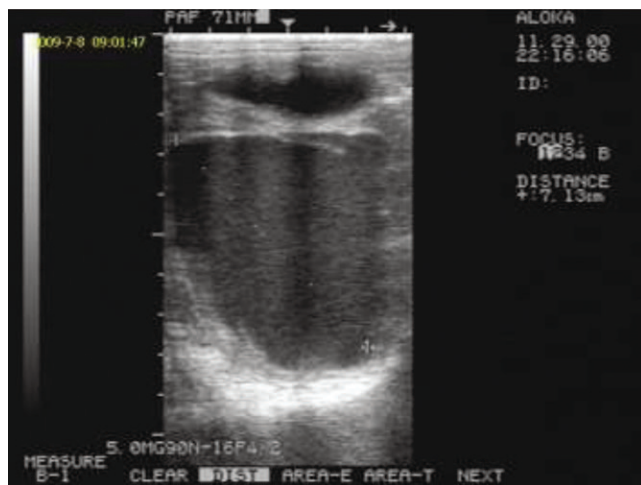


Fig. 1. Ultrasound image of a persistent anovulatory follicle in a mare.

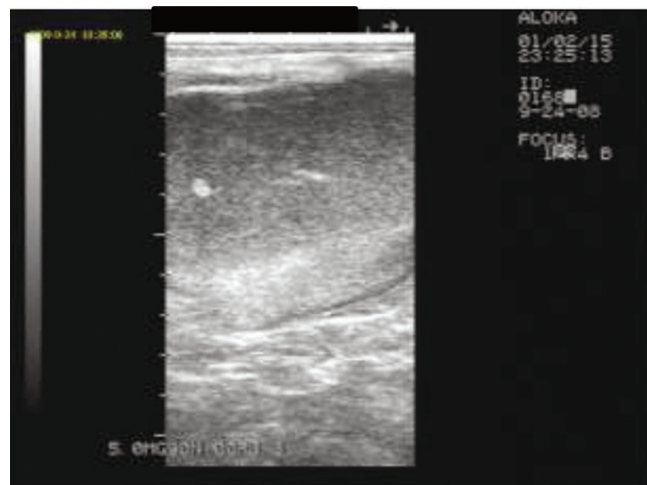


Fig. 3. Ultrasound image of unclotted blood within the follicular lumen. In real-time the fluid within the follicle would swirl upon manipulation.

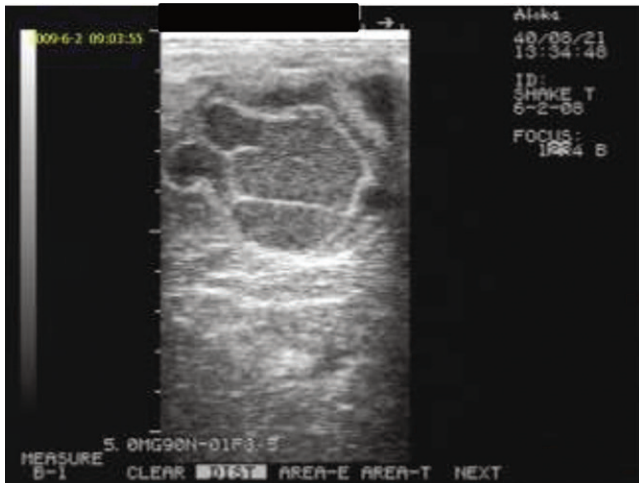


Fig. 4. Ultrasound image of hemorrhage within the lumen of a follicle. The echogenic material (blood) was noted to swirl within the follicular lumen.

examination, and a blood progesterone concentration above 1.0 ng/mL.

3. Premature Luteolysis

Premature destruction of the corpus luteum (luteolysis) is associated with an early onset of estrus and a decrease in the interovulatory interval. Detection of a smaller-than-predicted corpus luteum (Fig. 7) in association an early onset of endometrial edema is the clinical hallmark of premature luteolysis. The most common cause of premature luteolysis in the mare is bacterial endometritis,⁹⁻¹¹ which may be associated with the presence of echogenic fluid within the uterine lumen (Fig. 8). Inflammation of the endometrium can result in sufficient synthesis and release of prostaglandins to cause luteal regression. A combination of uter-

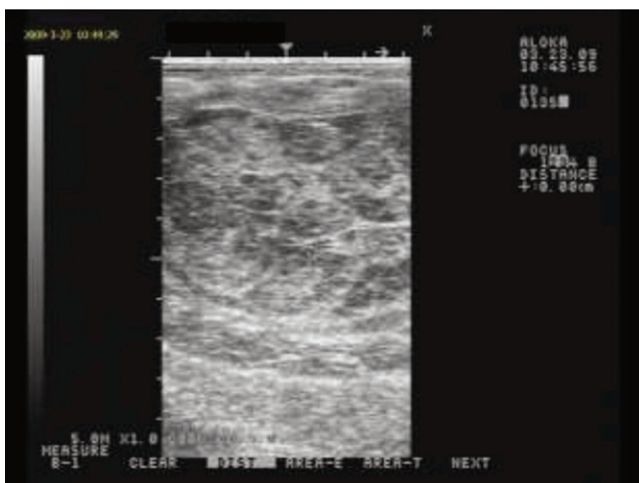


Fig. 5. Ultrasound image of a luteinized anovulatory follicle filled with echogenic material.



Fig. 6. Ultrasound image of a persistent corpus luteum in a mare.

ine culture and cytology should be performed in a nonpregnant mare to determine whether a uterine infection is present.

4. Ovarian Tumors

Ovarian tumors may arise from the surface epithelium, ovarian stroma, or germ cells. The most common ovarian tumor in the mare is the granulosa cell tumor (GCT). Other ovarian tumors such as cystadenomas, teratomas, and dysgerminomas are considered to be rare in the horse.¹²

GCTs are almost always unilateral, slow growing, and benign. GCTs are hormonally active and behavioral abnormalities such as prolonged anestrus, aggressive or stallion-like behavior, and persistent estrus may be expressed in affected mares.¹³ Diagnostic techniques used in the detection of an ovarian tumor are palpation and ultrasonography and hormone analysis.

The most common ultrasonographic presentation of an equine GCT is a unilaterally enlarged multicystic ovary with a small inactive contralateral ovary (Fig. 9). However, a GCT may occasionally present as a solid mass or as a single large cyst (Fig. 10). Inactivity in the contralateral ovary is due to suppression of pituitary follicle stimulating hormone (FSH) secretion by inhibin and other hormones produced by the tumor.¹³

Endocrine tests used to detect or confirm a GCT include measurement of a panel of inhibin, testosterone and progesterone, or the analysis of Anti-Müllerian hormone.^{12,14} Inhibin is elevated in approximately 90% of mares with GCT, whereas testosterone is elevated in 40% to 50% of affected mares and only if there is a thecal cell component to the tumor (i.e., a granulosa-theca cell tumor). Progesterone is not usually elevated in mares with a GCT. Anti-Müllerian hormone levels in mares with GCTs are significantly higher than in nonaffected

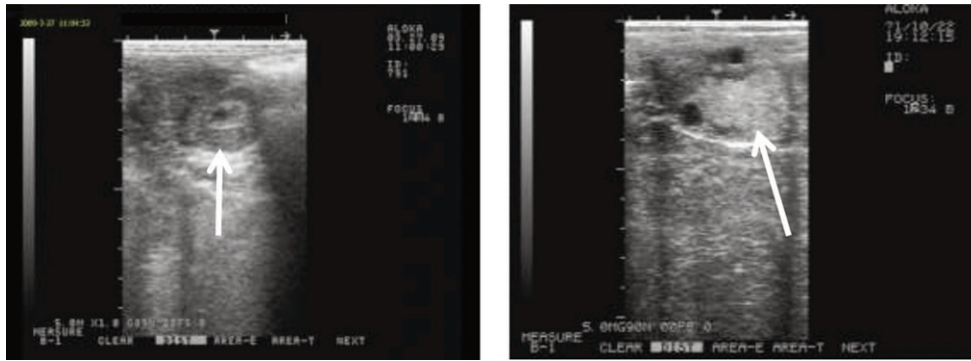


Fig. 7. Ultrasound image of a corpus luteum undergoing premature luteolysis (left image) and a normal corpus luteum (right image).

mares and have a 98% sensitivity in the detection of a histologically confirmed GCT.¹⁴

Other ovarian tumors, such as cystadenomas, teratomas, and dysgerminomas are very rare, not hormonally active, and do not cause either behavioral changes or suppression of activity in the contralateral ovary.

5. Ovarian Hematoma

The term ovarian hematoma refers to excessive post-ovulation hemorrhage resulting in ovarian enlargement. An ovarian hematoma has ultrasonographic characteristics of an enlarged corpus hemorrhagicum (Fig. 11). Fibrin strands traverse through a pool of congealing echogenic fluid as the blood clot begins to form. Subsequent examinations reveal increased echogenicity as the process of cellular infiltration and luteinization occurs. Given that ovulation occurred prior to formation of the ovarian hematoma, affected mares have the ability to become pregnant.

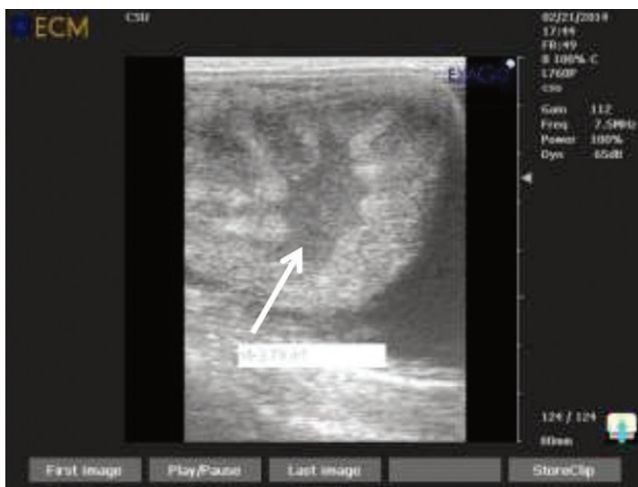


Fig. 8. Ultrasound image of echogenic fluid in the uterus of a mare with endometritis due to *Streptococcus equi* subsp. *zooepidemicus*.

6. Failure of Follicular Development

Alterations of follicular development may be associated with a variety of physiological and pathological conditions.

Ovarian Senescence

Ovarian dysfunction has been identified as a cause of reduced fertility in mares approximately 20 years of age or older. Ovarian issues in older mares include a longer follicular phase, prolonged interovulatory period, and delay in the first ovulation of the year.¹⁵ Complete failure of follicular development or ovarian senescence has been observed in aged mares and may be due to an insufficient number of primordial follicles. An ultrasound examination of a mare with ovarian senescence would reveal an absence of follicular activity (Fig. 12). No effective treatments are available for promoting follicular growth in senescent ovaries.

Postpartum Anestrus

A majority of mares develop follicles and ovulate early in the postpartum period (i.e., foal heat ovulation) and continue to cycle if they are not bred or do not become pregnant. However, some mares may exhibit a temporary failure of follicular development or ovulation after foaling.¹⁶ Affected mares may remain anestrus or anovulatory for weeks or months before cyclic ovarian activity is initiated. Mares that foal early in the year are more prone to exhibit postpartum anestrus than mares foaling later in the spring or in the summer. "Postpartum anestrus" may be caused by the combined effects of season, nutrition, and lactation. Ultrasound examination of a mare exhibiting postpartum anestrus may reveal multiple small- to medium-sized follicles (i.e., 15 to 25 mm in diameter), but usually an absence of endometrial edema (Fig. 13).

Exogenous Hormone Treatment

Administration of anabolic steroids, dexamethasone, estradiol esters, and a combination of progesterone plus estradiol have all been reported to

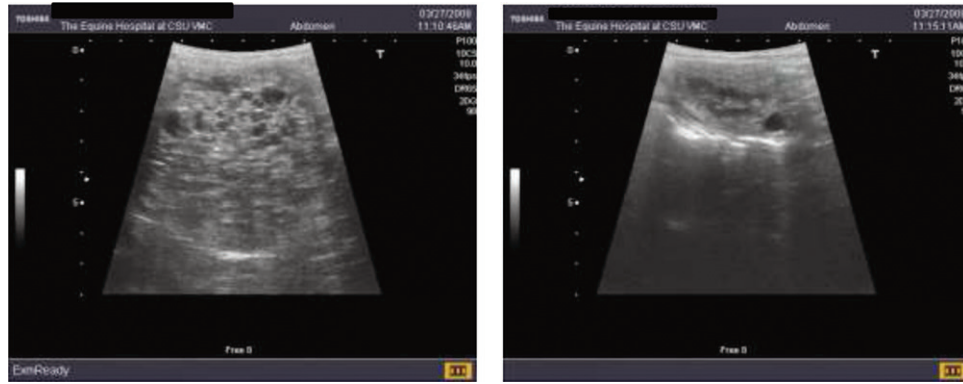


Fig. 9. Ultrasound image of an ovarian GCT (left) and a small contralateral ovary (right). Note the multicystic “honeycomb” appearance of the tumor.

suppress pituitary gonadotropin secretion and ultimately result in inhibition of ovarian follicular activity.^{17–19} Implants containing potent agonists of gonadotropin-releasing hormone (GnRH), such as deslorelin acetate, have been demonstrated to cause down-regulation of pituitary gonadotropin secretion and short-term alterations in ovarian function.²⁰ An ultrasound examination of ovaries of mares adversely affected by exogenous hormones would reveal limited follicular activity.

GnRH Vaccine Administration

Active immunization of mares against GnRH results in suppression of pituitary FSH and luteinizing hormone (LH) secretion and a subsequent reduction in ovarian follicular activity, suppression of estrus, and decreased fertility that is related to the magnitude and duration of antibody titer.^{21–23} In most instances, the effect is reversible over time as antibody titers wane and vaccinated mares eventually resume ovarian function and return to normal fertility. However, a limited number of mares im-

munized against GnRH have been noted to fail to have recrudescence to cyclicity even after several years.²⁴

7. Luteal Insufficiency

Primary luteal insufficiency implies a deficiency in progesterone production by the corpus luteum that forms after ovulation. Luteal insufficiency has been suggested to be a cause of subfertility in mares, although data are limited.²⁵ Clinically, luteal insufficiency may be noted most commonly 14 to 16 days after ovulation in pregnant mares with a small regressing corpus luteum. The cause of the luteal insufficiency is likely to be failure of maternal recognition of pregnancy. Supplementation with exogenous progestins can successfully maintain the pregnancy in the absence of endogenous progesterone. Ultrasound examination of a pregnant mare with luteal insufficiency typically reveals a small corpus luteum along with mild-to-moderate endometrial edema in addition to an embryonic vesicle (Fig. 14).

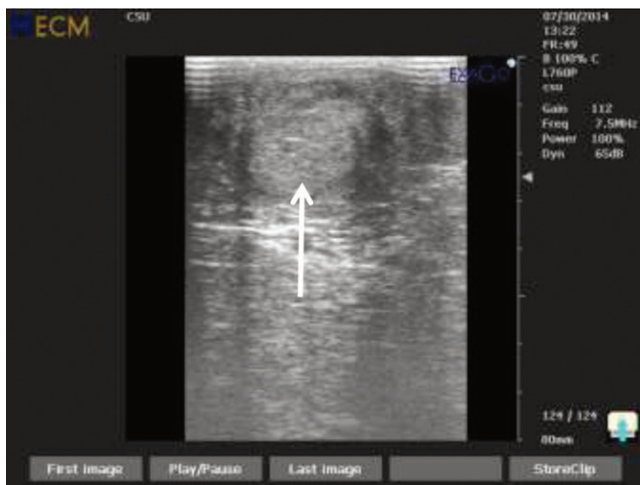


Fig. 10. Ultrasound image of a GCT that was a uniformly echogenic structure.



Fig. 11. Ultrasound image of an ovarian hematoma in a mare.

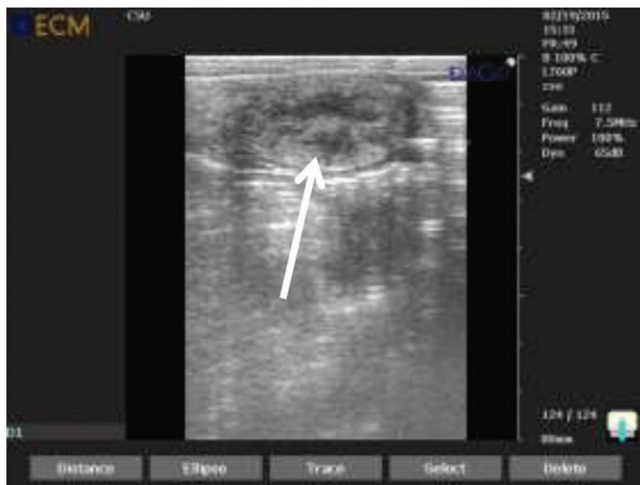


Fig. 12. Ultrasound image of an ovary of an aged mare with ovarian senescence. Note the complete absence of follicles.

8. Epithelial Inclusion Cysts

Cysts within the region of the ovulation fossa or adjacent to the ovary may be observed during a routine ultrasonographic examination.²⁶ Epithelial inclusion cysts (or “ovulation fossa cysts”) arise from the surface epithelium that lines the ovulation fossa that becomes embedded within the ovarian cortex following ovulation. Epithelial inclusion cysts may interfere with fertility if they obstruct the ovulation fossa and are more common in older mares. Ultrasonographically, epithelial inclusion cysts are identified as a cluster of small cysts filled with clear (nonechogenic) fluid in the center of the ovary in the region of the ovulation fossa (Fig. 15). No treatment is necessary or warranted.

9. Parovarian Cysts

Parovarian cysts (or “fimbrial cysts”) arise from embryonic vestiges and cystic accessory structures. Small fimbrial cysts generally do not interfere with ovulation or oocyte transport, respectively, and are



Fig. 13. Ultrasound image of a mare in “post-partum anestrus.”

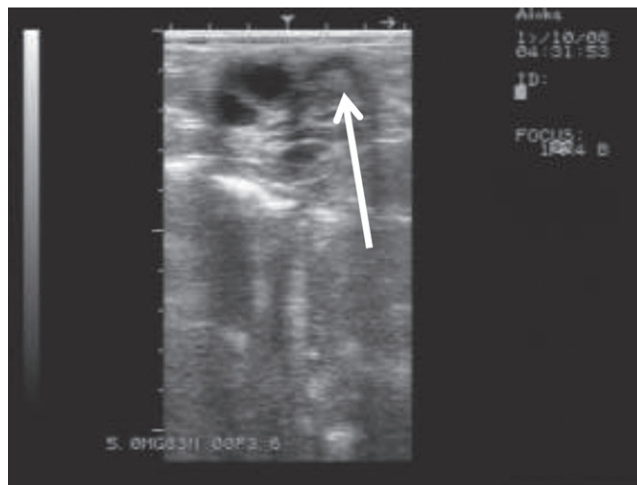


Fig. 14. Ultrasound image of a small, inactive corpus luteum in a pregnant mare 16 days after ovulation. Serum progesterone concentration in this mare was 0.7 ng/mL.

not usually associated with reduced fertility.²⁷ Parovarian cysts can be small (<10 mm) to large (>30 mm) fluid-filled structures adjacent to the ovary (Fig. 16). Parovarian cysts may be inadvertently mistaken for an ovarian follicle. Differentiation between a parovarian cyst and an ovarian follicle is often made by manual palpation per rectum.

10. Chromosomal Abnormalities

A chromosomal abnormality may be suspected in a mare of breeding age with primary infertility and gonadal hypoplasia.²⁸ The most commonly reported chromosomal abnormality of the horse is 63, X gonadal dysgenesis, in which only a single sex chromosome is present. Horses with gonadal dysgenesis develop as phenotypic females because of the absence of a Y chromosome. Affected horses

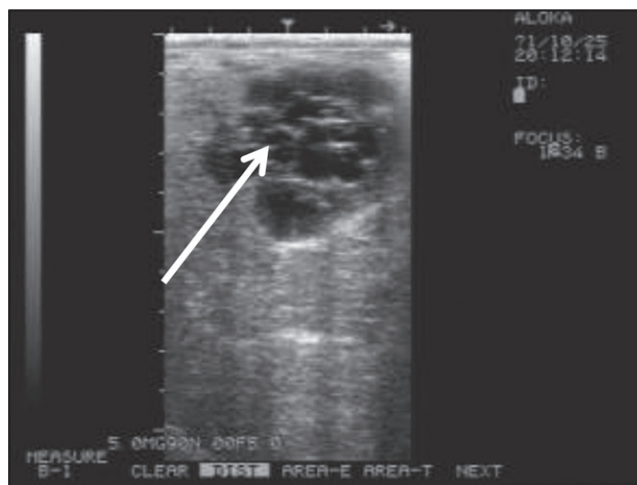


Fig. 15. Ultrasound image of a cluster of epithelial inclusion cysts adjacent to the ovulation fossa of a mare.



Fig. 16. Ultrasound image of a large parovarian cyst adjacent to the ovary of a mare.

have bilaterally small ovaries (Fig. 17), a small flaccid uterus, and endometrial gland hypoplasia. Numerous other chromosomal abnormalities have also been reported in the mare. Definitive diagnosis of a chromosomal abnormality is based on chromosome analysis or karyotyping.

11. Summary

The most common ovarian abnormality is the hemorrhagic anovulatory follicle that eventually luteinizes to form a luteinized anovulatory follicle. The GCT is the most common ovarian tumor of the mare and is characterized by a unilaterally enlarged ovary and a small inactive contralateral ovary. Failure of follicular development is a common manifestation of several abnormalities affecting the ovaries including administration of anabolic steroids, vaccination against GnRH, post-partum anestrus, and ovarian senescence.



Fig. 17. Ultrasound image of an ovary of a mare with 63, X gonadal dysgenesis. Note the complete absence of follicular activity.

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.

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Exploring the “Hidden Curriculum” in Equine Practice

Betsy Charles, DVM

The “hidden curriculum,” although commonly explored in health care teaching environments such as veterinary school, is not necessarily considered in private practice settings. Are there things we as practicing veterinarians do that further support the hidden curriculum that begins to be taught in veterinary school? This paper will examine the concept of the hidden curriculum and apply this concept to the private practice setting in order that equine practitioners can better understand its implications for overall wellness in the profession. The paper will serve as an outline to stimulate discussion during the convention meeting. Author’s address: 29083 Bent Tree Drive, Murrieta, CA 92563; e-mail: betsycharles@mac.com. © 2017 AAEP.

1. Introduction

The hidden curriculum is an informal set of norms, practices, or values that are taught and modeled to students. It is defined as “the unwritten, unofficial, and often unintended lessons, values, and perspectives that students learn in school.” It is outside the objectives outlined in formal course syllabi.¹ The hidden curriculum can either offer support to the information taught within the formal curriculum or it can undermine these lessons. It is this collision between either support for and/or undermining of the curriculum that needs to be considered. What are we teaching our equine interested students about the practice of equine medicine and surgery? Are the things we are teaching via the hidden curriculum positive or negative and do they support the development of healthy equine practitioners?

Specifically, agreement about whether a hidden curriculum exists should be examined. If yes, a definition for the curriculum taught in the equine sections of veterinary school across the United

States should be examined. In the context of an educational environment like veterinary school, the concept of a hidden curriculum makes sense because the purpose of an educational institution is to teach. Thus, within this context it seems reasonable that unintended lessons may be transmitted to students from faculty members along with the more formal curriculum. Often, these unwritten lessons are not positive.

In her article written for the *New York Times* in 2009, Dr. Paula Chen wrote about the hidden curriculum in human medical education.

While most of medical education and training is about the nuts and bolts of clinical care—how to treat hypertension, how to manage a ventilator, how to take out a gallbladder—the process also involves learning how to be “a doctor.” As opposed to lessons covered in textbooks and classrooms, this kind of learning is done through modeling, or what medical sociologist F. W. Hafferty has called the “informal” or “hidden curriculum.”

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Medical students and residents copy the lingo, manners, and expressions of more established senior residents and attending physicians. The lessons from these role models, who are often tired and stressed out themselves, can be sobering. They are also often cynical, rooted in large part in the belief that a doctor's level of compassion is fixed.²

As Dr. Chen points out, it is often the hidden curriculum that teaches us how to "be doctors" and therefore plays a big role in defining the culture of practice. To change what it means to be a doctor, we must acknowledge the underlying hidden curriculum.

2. What Is the Hidden Curriculum in Equine Practice?

The idea of a "hidden curriculum" in equine practice is of great interest to the author as much of her career has been spent trying to increase the veterinary profession's capacity for understanding leadership and wellness and how, when these two concepts are successfully tied together, they lead to career fulfillment. This pursuit has resulted in learning about what it means to be an equine practitioner by visiting over three quarters of the nation's veterinary schools, having hundreds of conversations with practice owners, associates, technicians, and support staff, engaging numerous American Association of Equine Practitioners members through various leadership events, and learning through the author's own experience in equine practice. Through these experiences and conversations, the same points come up over and over again. Namely, that we, as equine practitioners, say we want to lead and be well, but that our actions do not line up with what we say. Often, students comment on this double standard in their courses and labs. For example, it is not uncommon for faculty members to talk about the importance of life balance with their students while working 60+ hours a week themselves and expecting students to do the same. New associates who were hopeful the double standard would change once they got into practice are discouraged when they realize it remains the same in practice. From veterinary school into practice, the old adage, "Do as I say, not as I do," is common.

The research is beginning to document that in order to lead effectively, one must be well.³ If this is true, what are our veterinary schools doing to foster the skills associated with wellness and leadership in equine practice? What are practice owners doing to support these skills? What exactly is the "hidden curriculum" within equine education and practice?

Through discussion with numerous program participants at state and national meetings and conversations with students and practitioners, the following ideas have been presented as components of the hidden curriculum of equine practice:

- Long hours at work are necessary and reasonable.
- Taking time for yourself is unnecessary.
- Emotions have no place at work.
- Asking for help is for people who are weak and unorganized.
- Negative reinforcement is a necessary component of medical training.
- Doctors never make mistakes and, in the rare case that they do, talking about the mistake is not appropriate.

3. Strategies for Acknowledging the Hidden Curriculum

In January of 2009, a study was published in *Academic Medicine* about how we can begin to shift the culture of medicine and address the negative lessons physicians learn through the hidden curriculum. Through faculty development, clinicians can be given the skill sets necessary to foster a positive approach to teaching.⁴ Dr. Chen writes about that study, "A new study published in this month's issue of *Academic Medicine* proves that effort does matter, and that learning is possible. Even established clinicians can be re-inspired to adopt new humanistic skills, becoming better teachers and role models in the process."³ Discussion about these ideas will lead to a better understanding of their merit and possible strategies to combat the negative consequences of these hidden lessons that are being taught. More research is needed to further define how the hidden curriculum is affecting equine practitioners, but in the meantime, we can begin to shift the culture of equine practice toward one that supports leadership development and wellbeing by having open and honest conversations about the double standard that currently exists in our veterinary schools as well as in practice.

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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Equine Doctor, Know Thyself—The Key to Keeping Yourself Healthy

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He who knows others is wise.
He who knows himself is enlightened.
—Lao Tzu, *Chinese philosopher*
(604 BC–531 BC)

1. Introduction

Published studies, nationally and internationally, consistently report that veterinarians are at higher risk for mental and addictive ill health versus the general population. The statistics are alarming; they document a reality within our profession that must spur us to action—both in our own lives and in the context of our larger profession.

- Male and female veterinarians have a relative risk 5.62 times and 7.62 times, respectively, higher than the general population for deaths certified as suicide.¹
- Repeatedly studies show higher percentages of veterinarians reporting characteristics consistent with anxiety disorders and depression compared with the general population.²
- A study from the United Kingdom screened veterinarians for “at-risk drinking” reporting 62.5% of those screened were positive.¹
- Anecdotal evidence highlights an increased use of narcotics among veterinarians, as

reported by Physician Health Programs nationally.³

Conversely, there is evidence of a disconnect between a veterinarian’s self-perceived risk for mental and physical ill health and published statistics of the actual risks. There are wide discrepancies in the percentage of veterinarians who report mental, physical, and addictive illness and those seeking treatment.⁴ Many veterinarians are not aware of what resources are available to them for mental or addictive health issues. Many veterinarians do not identify issues of mental health, addiction or well-being, in the context of their work lives, or identify them as issues of relevance for the profession.

2. Emotional Quotient

The veterinary profession has historically placed value on and rewarded intelligence and scientific rigor. Our profession values Intellectual Quotient (IQ); the value of science, knowledge, and cognitive ability. In addition, our profession values business success, profit, and practice growth. Emotional Quotient (EQ) is a measure of self awareness, empathy, and sensitivity; it is a measure of “emotional intelligence.” Historically our profession has not placed value on EQ in our education, training, or in practices.

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As a profession, and as individuals, we do ourselves a disservice by focusing on IQ to the exclusion of EQ; a veterinarian's mental and physical wellbeing relies upon a robust EQ.

- EQ affects our ability to lead, motivate, and excel at work.
- EQ affects our ability to manage stress. Stress left unchecked, can contribute to many health problems such as heart disease, obesity, diabetes, and high blood pressure.
- EQ affects our ability to manage anxiety and depression. Anxiety and depression directly affect our mental health and addictive behaviors.⁵

EQ affects our ability to understand and express feelings. This ability is a component to communicating well with others and forging strong relationships.⁵

3. Self Awareness

Self awareness is one of the four key components of EQ. The other key components of EQ—self management, social awareness, and relationship management—build off of self awareness. Self awareness is a logical “starting point” to developing a robust EQ.

Self awareness is the ability to recognize our strengths and our weaknesses. Awareness of our strengths allows us to fully utilize the best parts of ourselves, to marshal those strengths for our best chance at success. Awareness of our weaknesses gives us the opportunity to improve and the opportunity to minimize our weaknesses, which may sabotage success. Awareness of ourselves and understanding how others perceive us is important in earning their trust.

Self awareness must involve a decision to want to be more curious about Self. Becoming self aware is a process of better understanding yourself, and should not be negatively focused on judgment. What makes you tick? What do you “need?” What do you bring to the table? Who are you and who do others think you are? Becoming self aware is a process that involves gathering feedback from within (self assessment) and from others. There are tools to help organize the process for becoming more self aware.

4. Tools

- Meyer Briggs Type Indicator (MBTI).⁶ The MBTI was originally developed in the 1940s by Katharine Cooks Briggs and her daughter, Isabel Briggs Meyers, with inspiration from the theories of Swiss psychiatrist Carl Jung. The MBTI assessment tool identifies a person as one of 16 different personality types. The goal in identifying your personality type is to achieve a greater understanding of yourself

and yourself in relation to others. There are four dimensions at the heart of MBTI:

- Where you focus your attention
- How you take in your information
- How you make decisions
- How you orientate yourself in the world
- Dominance, Influence, Steadiness, and Conscientiousness (DiSC).⁷ The DiSC self-assessment tool is a nonjudgmental method providing a common language to better understand yourself, your behaviors, and how you can adapt your behaviors with others.

In 1956, a psychologist, Walter Clarke, was the first to build this tool, building on the theories of psychologist, Dr. William Moulton Marston. Similar to MBTI, the premise is to increase self knowledge but by identifying an individual's composition of four different “styles:” dominance, influence, steadiness, and conscientiousness. The styles evaluate the following:

- How you respond to conflict
- What motivates you
- What stresses you
- Problem-solving style

DiSC and MBTI are just two well-known self-assessment tools that help create self awareness. There are other tools for becoming self aware that are more “organic;” they don't involve the “test-taking” approach of the MBTI or DiSC tools. Self awareness doesn't start and end with a personality designation from a tool, but rather is an ongoing process requiring commitment, time, and practice. Tools, or practices, that reflect the ongoing process of self-awareness include the following:

- Mindfulness practice
- Yoga
- Meditation/religion/prayer
- “Forest bathing” aimed at immersion in the natural environment through the smells, textures, tastes, and sights of the forest to provide a physical and mental stress reduction strategy.⁸

“The ultimate value of life depends upon awareness and the power of contemplation.” ~Aristotle

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Conflict of Interest

The Author has no conflicts of interest.

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Foundations of Inventory Management

Melissa Mauldin, BSBA, CVPM

Inventory management can have a huge effect on the financial performance of your practice. This session will review common inventory terms and techniques to help you better manage your practice's inventory and improve your bottom line. Author's address: 7601 Della Drive, Ste. 17, Orlando, FL 32819; e-mail: melissa.mauldin@petpartnersusa.com. © 2017 AAEP.

1. Introduction

In most, if not all, veterinary practices, inventory is the one of the largest expenses, second only to staffing costs. Lack of proper inventory control can result in poor cash flow and loss of profitability. Because of this, it is important that team members practice fiscal responsibility when ordering supplies and stocking the hospital. The goal of this session is to introduce to you the basics of inventory management, as well as common key inventory terms, to help you better understand and streamline your inventory. As a practice manager, technician or inventory manager, this is a way for you to have a positive effect on your practice's financials and help the profitability of your hospital.

What exactly is inventory? Inventory is defined as all goods owned and held for sale or use in the regular course of business.¹ This includes your prescription medications, diets and preventatives, as well as your medical supplies such as gauze, suture, syringes, needles, injectables, etc. It does not include medical equipment (even small medical devices) or office supplies. Inventory may be managed by a doctor, a practice manager, or an employee who has been designated the inventory manager. Although other team members may help in the ordering or receiving process, there

should be one person ultimately responsible for oversight and training of the practice's inventory management.

Many times, we only take into account the actual cost of the products we order, but there are many costs pertaining to inventory other than the outright costs of the product. One type of additional costs are called *holding costs* and often account for an additional 8–15% of the unit cost.² These costs can include any pharmacy licensing fees, sales and use taxes, building and storage costs, and insurance premiums to protect the inventory and costs resulting from loss and expiration. Holding costs also take into account the opportunity costs of money spent tied up in inventory sitting on the shelf that could be used in other ways. *Ordering costs* must also be considered. These costs can account for 15–20% of unit costs, and are mainly composed of labor costs. The labor costs involved in inventory management might include time spent curating an order, placing the order, meeting with vendors, searching for the best prices, receiving an order, filing paperwork, and associated computer work. Both ordering costs and holding costs can be minimized by developing a streamlined ordering process with appropriate ordering quantities.

So how do we limit holding and ordering costs? We first need to determine what is an appropriate

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amount of inventory to have on hand. When determining appropriate stocking levels, we need to consider reorder points, reorder quantities, par levels and lead times. A reorder point is the inventory level that triggers a reorder of a specific item. A reorder quantity will tell us how much needs to be ordered. A par level is the optimal amount of something that we want to have on the shelf, and if our stock levels dip below that, we order up to it. Lead time is considered the amount of time that it takes to receive an item once the order is placed. If we want to only order once a week, we want to take that into consideration when determining lead time for an item. Luckily, many of our vendors offer delivery within 2–3 days, with many offering next day delivery, which can help us dramatically reduce the amount needed to keep in stock at one time.

To determine your reorder point for a given item, you want to forecast how much inventory you will use before your next order. This is so you do not run out of the item while you are waiting for the new order to arrive. Your practice management software is a great resource for this. You can run a report to see how much of each item was sold in a specific timeframe, and divide that amount by the number of days you were open. This is your average daily usage. You can multiply your average daily usage by your lead time to determine your reorder point. Also, consider rounding up or adding a few extra days to your lead time for popular products to give yourself a little extra protection from stock outs.

Your reorder quantity will vary by product. It is ideal to have no more than 30 days' supply of an item on your shelf at one time. If your goal is to order an item once a month, your reorder quantity will be the amount you sell, on average, within a 30-day period. If you order weekly, you might also have items that you are only ordering a 1–2-week supply at a time. Sometimes we are limited by product packaging. For instance, many common medications come in 1000-count bottles. That may last us more than 30 days, but purchasing in that quantity can be more economical than ordering smaller-quantity bottles. In the next session, we will discuss how to determine these figures and put it all together to create an efficient inventory system.

Another helpful inventory term is turnover. An inventory turn, or turnover, is the number of times that an item is used and replaced during the year. Some items will have a lower turnover than other items, but a good rule of thumb is approximately nine turnovers per year of your entire inventory. The higher your turnover number in a given period, the more efficient inventory. Be cautious about trying to get this number too high; there are ordering costs every time you place an order. The higher your inventory turn, the lower your amount of inventory, which takes vigilance to avoid stock outs. With time, you will find the right balance of how often to order and the costs involved.

Determining your inventory turnover is a two-step process. First you will need to determine your average inventory, then you will use that to help determine your turnovers. See equations below for examples. You can use your turnover number to gauge how you are improving your inventory efficiency by calculating it at regular intervals.

Average inventory on hand

$$= (\text{beginning inventory} + \text{ending inventory})/2$$

Inventory turns = total purchases in

$$\text{inventory period/average inventory}$$

In addition to ordering efficiencies, you will also need to think about the financial side of your inventory practices, including pricing. Practices often choose to price items based on either a markup or margin philosophy. Margin is the difference in the cost and a selling price of an item. When using margin pricing, you will want to consider all costs involved, including holding and ordering costs, overhead, doctor commissions, and desired profit. Another pricing philosophy is markup, in which the price is set based on a percentage of the cost. For example, a 200% markup is three times the unit cost (200% of the product cost is added to the cost of the product). Many practices use a combination of practice philosophies to make their pharmacy successful. Some items will have smaller margins or markups and be considered “loss leaders” and be subsidized by other items in your pharmacy with a higher margin or markup.

One of the most difficult, but most important, tool in efficiently managing your inventory is alignment and buy in from your doctors and your team. Getting your doctors in alignment on a majority of your products will help you consolidate your inventory and have fewer items to order. With fewer items to order, you will be able to have more of one item on the shelf without fear of stocking out. The challenge here is that doctors often come to us with product preferences based on what they learned in school or used at their previous practice, and they do not want to be told what they have to use. All of which is understandable. Product selection should always be a discussion with the doctor team to ensure that everyone is onboard with the decision. If you find that you have a serial problem in your practice of having multiple items that serve the same purpose, start small. Do not start with forcing your doctors down to one, or even two, products. Make it a goal to eliminate one or two of those items, starting with the least used ones. These items can be special orders or moved to an online pharmacy.

An online pharmacy is another great tool that can benefit your practice, particularly if you perform a lot of house calls or farm calls. There are several great options out there. An online pharmacy can be linked to your website so that clients can go to your

website and order products that come from your hospital's online pharmacy, which is stocked by accredited pharmacies that work with our regular vendors to help us better serve our clients. What this means for us is that we do not have to carry every item available to better serve our clients, because they can get the products from our online pharmacy and we still earn a small profit off the items. Another benefit of an online pharmacy is that if we are seeing the patient outside of the office, we still have a pharmacy at our fingertips.

One final thing to remember is to keep it simple. Find a distributor that works for you based on pricing, service, and product offerings, and order a majority, if not all, of your supplies through them. Shopping around every week for the best price ends up costing you more in the long run due to increased ordering costs. Although there are a lot of details and numbers involved in inventory management,

do not over complicate the process. Simplicity and structure are key to making inventory management something everyone in your practice can take part in. And when everyone buys in, you will be successful!

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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Controlling the Chaos: Creating Your Inventory System

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1. Introduction

Inventory management can have a huge effect on the financial performance of your practice. This session will give you direction on how to create an inventory system that helps bring order to the chaos and maximize your profitability.

Does your inventory drive you crazy? How often do you run out of something you need or see something sitting on the shelf that has not moved in months? An inventory system can help! Creating an inventory system can be a time-consuming and tedious process but in order to control the chaos that is your inventory, it is very necessary. This session will review the steps to take to design an inventory system for your practice as well as offer a few options that will make ordering easier for you.

The first step in creating an inventory system is to decide what items you are going to stock. This may not be as easy as it sounds. If you do not have a system already in place you cannot assume that because it is on your shelf that you are going to continue ordering it. Before you move forward, you must have a conversation with ALL of the doctors at your practice and determine which items you will stock. In some cases it will be obvious because you only have one or two options, whereas in others you may find that you have seven different items that serve the same purpose. If you find items in the latter situation, come to the meeting prepared. Perform a search in your practice management soft-

ware (PIMS) to determine how much you are actually selling of each of the items and propose to eliminate the bottom two products from your in-house stock. You may eventually whittle that down more, but it is okay to start small to allow the doctors and team time to acclimate, if necessary.

Once you have your list of items that will be stocked, it is time to find sales history on these items. Your PIMS should have reports with that information, or you can also receive that information from your vendors. Use caution in relying on your purchase information at this time. If you have not had a streamlined process, it is possible that your purchases may not be equal to your sales, which could give you incorrect information. You will use this information to determine your reorder points and reorder quantities. Because preferences can fluctuate, I like to use the previous 3 months of sales information to determine my reorder points and reorder quantities. Some people use the previous 12 months to get a broader view of the item.

To determine a reorder point, you want to take the sales from the time period you select and divide that by the number of business days in that time period. This will be your daily average usage. Multiply that number by your days of lead time (which will include the days until your next order), and you will determine your reorder point. You can use this same information to determine your reorder quantities by taking your daily usage and multiplying by the shelf life you want the item to have (generally no longer than 30 days).

NOTES

Table 1. Reorder List

Medication	ROP	ROQ
Acepromazine injection	3 bottles	6 bottles
Banamine	4 bottles	8 bottles
Rabies vaccine	25 doses	50 doses
EWT-WN vaccine	25 doses	50 doses
Bute paste	10 each	20 each
Dexamethasone	3 bottles	6 bottles
Tri-Hist granules	3 tubs	
Marquis	PAR: 6 tubes	
Cosequin	PAR: 10 tubs	

Abbreviations: ROP, reorder point; ROQ, reorder quantity.

At this point, you have a few different options. You will first need to determine whether you want to manage your inventory in your PIMS or manually. If you are manually managing your inventory, you will need to create a spreadsheet, update it with every item you stock, update your reorder points and reorder quantities, and do a manual count every week when you order. Table 1 shows an example of what that might look like.

This may work for smaller practices. For larger practices, this is a time-consuming event to perform every week. For better efficiency in larger practices, most PIMS allow for inventory management and control within the system. In this case, you will need to enter all of the reorder quantities and reorder points for each item into the appropriate area. You will also need to create purchase orders and receive them when the inventory is received into the hospital. Each PIMS is different, so if you are unsure of how to do this in your system, reach out to your software support for direction. Now, instead of counting each week, you will be able to run a report out of your system that alerts you when it is time to reorder. This report is called a reorder report, and in most systems it will list the item, how much is on hand, and what the reorder amount is. Because the information is only as good as what we put into it, you will still need to perform random spot checks, especially on high-demand items, to make sure your counts are accurate. It will be important to have your counts accurate in the computer so that your reorder information is accurate. Some PIMS also allow you to set up locations where the product is coming from, so if you have one item in multiple areas, you can deduct it from the correct location. This can be helpful if you have multiple departments or mobile kits.

Another option is a tag or flag system. In this system, items are “tagged” with a card at a determined reorder point. This card has vendor information and reorder amounts, so that the inventory manager knows what needs to be reordered and how much. This system is a little simpler, but does have a few drawbacks. For one, you have to be certain that the tag will make it to where it needs to go! When we are busy, sometimes things do not make it where they

need to be (stuff goes home in my pockets all the time). Also, it can also force higher reorder points, making you keep more on the shelf than really necessary. If your reorder point is 200 pills in a 1000-count bottle, there is not an easy way to “tag” 200 pills. You would likely reorder a bottle when one is depleted, always having an unopened bottle on hand. However, this system can work well for hospital supplies such as gauze, syringes, fluids, etc.

One of the most common manual inventory management system is the want list. This has benefits of being easy for everyone to access and can help the inventory manager spend less time determining what to purchase. However, the drawback of this is that it does not have any sort of structure around how much to order and when. While the easiest, it can also be the least effective with regard to profitability and inventory management.

In very large practices, you have the option of using a central supply concept in your inventory management. In the central supply concept, a majority of your inventory is kept in a locked central supply room, with only what is needed during the day being rationed out in other areas of the hospital. Benefits of this system include less potential for theft and waste, and a more efficient ordering system. The hospital areas would be stocked from the central supply area and the orders are placed based on the inventory levels of the central supply. By limiting access to a majority of your inventory, you are also protecting your practice from theft. Also, any discrepancies in counts can be determined more quickly and updated to keep electronic records current.

Regardless of the system that you choose, it is a wise decision to separate out the tasks involved in inventory management. For instance, a great checks and balances system is to have separate people place the order, put away the order, and receive the order into your software (if you are using electronic tracking). There should be an additional person who pays the invoices. This will limit any possibility of theft, diversion, or false orders. Although this can be challenging in smaller practices, it can work if you get your entire team involved in the process.

Inventory management can be a time-consuming task, but by following a streamlined process, it can become efficient and less chaotic. As inventory managers, it is our duty to properly manage what is one of our practice’s largest assets. It takes a great deal of preparation to initially get set up, but will pay dividends in time and profitability once it is in place.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

The Evolution of Horses and the Evolution of Equine Dentistry

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1. Introduction

Early Evolution of the Horse

The precursor of the horse was a small rabbit-sized animal called *Hyracotherium*, meaning “rabbit-like animal” (also known as The Dawn Horse or Eohippus) that evolved in North America during the Eocene era, circa 55 million years ago^{1,2} (about 10 million years after the dinosaurs died out due to a previous major climatic change). *Hyracotherium*, examples of whose skeletons can be seen in the Kentucky Horse Park Museum and in the National History Museum in London, browsed on a soft leafy vegetation diet and had *brachydont* (short crowned) teeth similar to human or canine teeth that coped adequately with this diet. *Hyracotherium* had a dental pattern consisting of three incisors, one canine, four premolar, and three molar teeth in each quadrant (similar to the mandibular dentition of a dog).² These four classes of teeth had different morphology and function (termed *heterodonty*). Great climatic changes at that time, including an increase in atmospheric CO₂, favoured the growth of more fibrous plants such as tundra grasses that replaced the previous more lush vegetation containing more simple carbohydrates (such as starches)

and proteins. These more fibrous plants contained higher amounts of complex structural carbohydrates such as cellulose, hemicellulose, pectin, and lignin in their cell walls. Subsequently, over the following millions of years, the digestive system, including the teeth, of *Hyracotherium* and its successors adapted in response to these dietary changes.

Cellulose is a complex carbohydrate composed of chains of d-glucose molecules attached by glycosidic bonds. It is the most common organic compound on earth, and thus the most common potential foodstuff. Astonishingly, no mammals have the digestive enzyme (cellulase) to enable them to utilise this widespread foodstuff, although some of the simplest of single-cell organisms such as bacteria and fungi possess these enzymes. Consequently, a major evolutionary step for the horse was to develop a great increase in the size of its large intestines (both caecum and colon), which together became a large fermentation vat for microbes that could digest cellulose-containing foodstuffs, in a symbiotic relationship with the horse. Subsequent to the microbial digestion of cellulose, the horse derives nutrition from volatile fatty acids produced from its microbial digestion and additionally from the breakdown products of these same microbes, when they die.

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A similar evolutionary development in ruminant's foreguts occurred approximately 20 million years later. However, unlike ruminants that later regurgitate and remasticate fibrous food at their leisure, horses have only a single opportunity to masticate their food into suitable sized particles for both endogenous (simple, noncellulose foodstuffs) and microbial cellulose digestion and this is one reason why equine digestion of cellulose is 30% less efficient than that of ruminants.³

An additional development in horses from Hyracotherium to the modern horse (*Equus caballus*) was a large increase in body size. Intermediate stages included Parahippus followed by a large increase in size occurring with Hipparion between 10 and 15 million years ago and later Merychippus and Pliohippus before the modern horse, *Equus*.^{2,3}

This increasingly sized horse would, like all herbivores, have been preyed upon by the large carnivores who lived at that time. The horse does not have the physical defense mechanisms against predators that some other species have, such as horns, claws, or large defensive teeth. However, it developed rapid acceleration and great speed to escape its predators, traits that we still utilize, especially in sport horses. The downside of this instant flight response is that when frightened, a horse does not usually consider the level of potential threat, be it another aggressive animal or a plastic bag flapping on a fence, it just runs! The severe wire injuries that horses sustain in comparison with other herbivore species that share the same paddocks, or jaw and incisor fractures with those sharing similar barn environments is a testament to this primitive reflex that saved their lives during their evolution, but now can be harmful. Foaling mares and neonatal foals would have been susceptible to predation and thus mares have a quick, very forceful parturition that can lead to a ruptured bladder in the foal and urogenital lacerations and bladder rupture in the mare, and fractured ribs are commonplace in neonatal foals.

Primitive horses occupied all of the Americas and then migrated to the "Old World" by the Bering Land Bridge that then connected modern-day Alaska with Russia on a number of occasions, their last migration being 2.5 million years ago.² These equidae became widely distributed in Asia where the *Przewalski horse* (66 chromosomes vs 64 in domesticated horses) developed much later, and to Eastern Europe where another primitive horse, the *Tarpan*, later evolved. Unfortunately, due to human neglect, the Tarpan was allowed to die out less than 100 years ago. Primitive horses also migrated onward to Africa where the Zebra evolved; the Middle East, where the ancestors of Arabian and Thoroughbred horses evolved; and Northern Europe, where the ancestors of Cold-Blooded horses such as Exmoor ponies and draught horses developed.

During the last ice age (circa 10,000 to 12,000 years ago) all equids died out in North and South

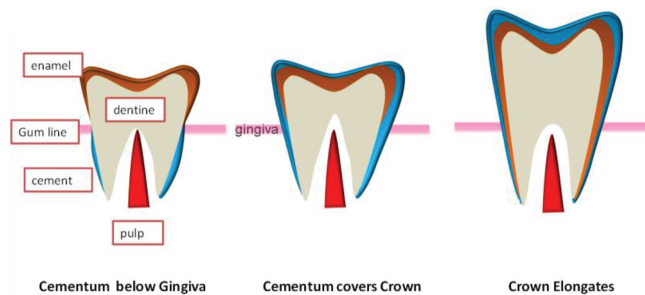


Fig. 1. Diagram depicting the evolution of hypsodont teeth. The diagram on the left shows a brachydont tooth with its clinical crown covered in enamel (brown) and all cement (cementum) (blue) lying subocclusally. The middle image shows cementum now covering the clinical crown. The right image shows the crown, that is now fully covered in enamel and cementum (a primary hypsodont occlusal surface) to be elongating. (Diagrams by Scott Pirie)

America ("The New World") where they had originally evolved. Horses were totally absent from this continent for over 10,000 years until reintroduced by the Spaniards circa 500 years ago. The current "wild" (more correctly termed *feral*) horses in North America (Mustangs) are descendants of these relatively recent imports. The Przewalski horse, native to Mongolia, is the only true remaining wild horse.

Evolution of Equine Teeth

A consequence of the change in diet from eating nutritious, simple foodstuffs, for perhaps a few hours a day, to browsing a low-calorie, fibrous diet that also contained many very hard particles of plant silicates termed *phytoliths*, and possible contamination with silicate-containing soil, for up to 18 hours/day, was that the existing short-crowned (brachydont) teeth would wear out quickly. Some other species adapted to such abrasive diets by rapidly replacing their teeth, for example, prior to the evolution of horses, *Diplodocus*, a 100 foot-long dinosaur, changed its teeth every 5 weeks, utilizing a rapid turnover of teeth rather than evolving teeth that were adapted to its abrasive diet!

The teeth of these early equids developed multiple evolutionary adaptations to cope with this major dietary change. These adaptive dental changes included an increase in tooth length (*hypsodonty*) to cope with the prolonged mastication (Figs. 1 and 2) and thus increased wear caused by the abrasive diet. There was simultaneous deepening of the jaws to accommodate these longer teeth.² They also developed prolonged (throughout most of their life) dental eruption (that differs from the continuous *growth* of teeth throughout life that occurs in rodents, i.e., *anelodont teeth*) to compensate for the above-noted high level of dental wear. Consequently, unlike brachydont teeth where only the roots lie beneath the gingiva, with all of the crown exposed in the oral cavity, horses evolved teeth with most of the crown

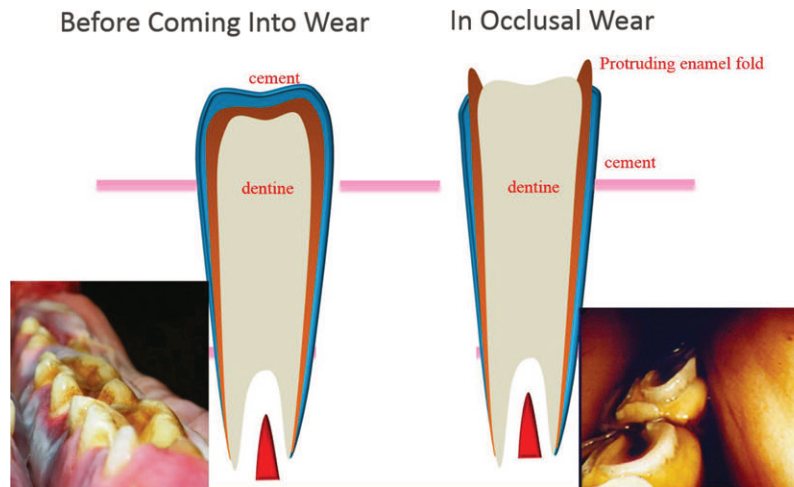


Fig. 2. With further elongation, the teeth are now hypsodont. At eruption the clinical crown is fully covered in enamel with overlying cementum, i.e., is a primary hypsodont surface (image of the primary surface of a neonatal mandibular cheek teeth on the left). Once the teeth come to wear, the cementum and enamel on the occlusal surface are quickly worn away exposing the enamel ridges on the permanent hypsodont occlusal surface (image of mature mandibular cheek teeth on right). This permanent surface has enamel folds protruding between the softer cementum and dentine, in a self-sharpening mechanism. (Diagrams by Scott Pirie)

lying subgingivally in a young horse as *reserve crown*, with the shorter *erupted* or *clinical crown* exposed in the oral cavity. A further change (like for many other herbivore teeth) was that equine teeth became less rounded/oval in shape with equine maxillary cheek teeth becoming squarer and wider than their rectangular-shaped mandibular cheek teeth.²

During its relatively rapid transit (1 to 3 days depending on particle size) of food through the equid intestines,⁴ microbes require a large surface area on the dietary cellulose to effectively digest it. Consequently, cellulose needs to be masticated into small particles for optimal endogenous and microbial digestion. To more effectively grind its food, a further equid dental adaptation was that the distribution of the three calcified tissues in its teeth also changed. These latter changes included development of infolding of the original layer of enamel around the periphery of the tooth (that still occurs in the crowns of brachydont teeth). This adaptation gave additional lengths of protruding (hard) enamel ridges because enamel, the hardest dental tissue, wears less than the adjacent dentine and cementum on the occlusal surface. These longer, protruding enamel ridges allow more effective shearing of fibrous food material between the occlusal enamel folds of the opposite teeth.

This peripheral enamel infolding is most marked in equid mandibular cheek teeth.⁵ However, the maxillary cheek teeth that have less enamel infolding, developed two cup-like infoldings of occlusal enamel (i.e., infundibulae) that extend almost 100% of crown length in young horses, to less than 10% in older horses,⁶ that give additional lengths of protruding occlusal enamel folds. The incisors developed a single infundibulum that extended less than

20% of the crown length, and so incisor infundibulae wear out in young adult horses. In contrast, cheek teeth infundibulae last almost until the teeth are fully worn, variably until 20 to 30 years of age in horses (later in donkeys).⁵ The enamel-free central areas of aged maxillary cheek teeth with worn infundibulae become excessively worn, that is termed *senile excavation*. The more apical aspects of mandibular cheek teeth reserve crowns have minimal peripheral enamel infolding and thus older equidae also develop *senile excavation* of their mandibular cheek teeth.^{5,7}

Another evolutionary change was that the more standard dental pattern of four premolars and three molars changed, with the first premolar becoming vestigial or absent (“wolf tooth”). Of interest is that in tapirs, another perissodactyl (along with the rhinoceros), and so a relative of horses, the first premolar remains as a full-sized premolar. The remaining equine three premolars increased in size and became identical to the molars, i.e., a process termed *molarisation* of premolars, with loss of their anatomical and functional differences (heterodonty).² As noted above, Triadan 06–08 (premolars) and the three molars (Triadan 09 to 11) are collectively referred to as *cheek teeth*.

Brachydont teeth, which form a continuous arch in some species, are kept in tight contact with each other by the rostrally, (in brachydont dentistry termed *mesial*, i.e., toward the median line) directed forces of the last molar (“wisdom tooth”)⁸ and also by rostrally directed pressure from normal occlusal forces during mastication. Having tight interdental (interproximal) contact between the occlusal aspects of teeth is even more important for herbivores that browse and masticate for up to 18 hours/day. In addition, horses produce enormous masticatory

Normal Angulation of Mandibular Cheek Teeth

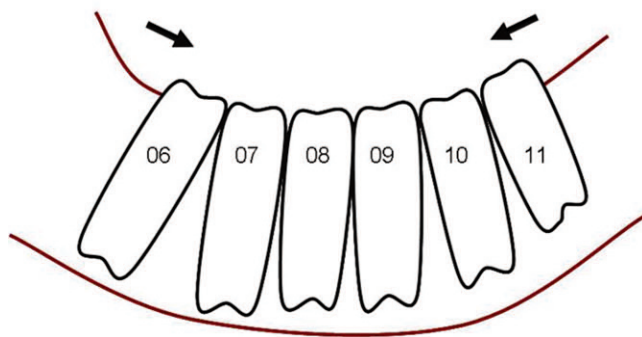


Fig. 3. Diagram illustrating the rostro-caudal angulation of the reserve and clinical crowns of young mandibular cheek teeth. The caudal cheek teeth, i.e., Triadan 10 and 11 clinical crowns are tilted rostrally (mesially), while the clinical crown of Triadan 06 is tilted caudally (distally). The eruption forces from the rostral and caudal cheek teeth should keep the occlusal surfaces of all six cheek teeth tightly compressed together.

forces (up to 2000 Newtons between their caudal cheek teeth).⁹ These high occlusal pressures force food into any potential spaces between the teeth, even into narrow spaces that are only intermittently created during the normal movement between individual adjacent teeth during mastication. These normal teeth movements in the latero-medial plane cause wear at the interproximal (interdental) contact areas and usually fully removes the peripheral cementum at these sites. In horses, the most caudal (Triadan 11 and to a lesser degree the Triadan 10) clinical crowns are angled rostrally (their reserve crowns are angled caudally) and so with their prolonged eruption they compress all of the cheek-teeth occlusal surfaces in a rostral direction (Fig. 3).

For unknown reasons, perhaps to lengthen the head to allow better visualisation of predators while browsing/eating, some primitive animals including the ancestors of equids, developed a space between their incisors/canines and cheek teeth, termed the *physiological diastema* or “bars of the mouth.” This in turn necessitated a further evolutionary development, i.e., of caudal angulation of the clinical crown of the first cheek tooth (Triadan 06) that compresses the occlusal surfaces of cheek teeth in a caudal direction; otherwise all of the cheek teeth would tip rostrally from the forces of the caudal cheek teeth (Figs. 3 and 4).

To enhance their masticatory function, the equine maxillary jaws and thus their maxillary cheek teeth became further apart than the mandibles and the mandibular cheek teeth (*anisognathia*). This difference is more marked between the caudal cheek teeth, with the maxillary rows being a mean of 23% wider than the mandibular rows and more so in donkeys.⁵ The occlusal angles of the teeth are higher in horses than in brachydont teeth even at birth, but they do not all have a 15° angle as was

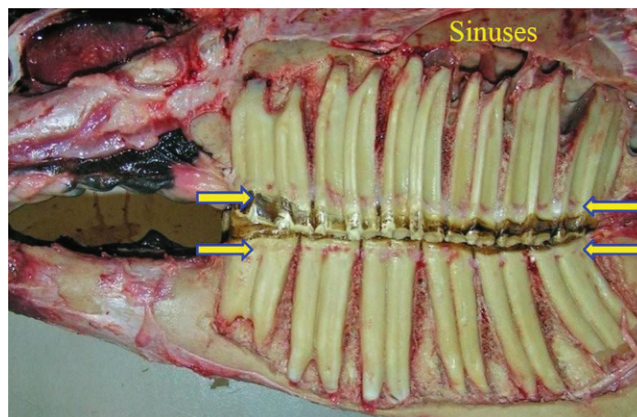


Fig. 4. This partially dissected head of a young adult horse shows the great length of the cheek teeth reserve crowns. The arrows show the direction of forces from the continued eruption of the rostral and caudal cheek teeth. (Dissection courtesy of Istvan Gere)

traditionally believed. The mandibular cheek-teeth occlusal angles vary from 15° on the rostral (Triadan 06s) to circa 30° to 35° on the caudal (Triadan 10s, 11s) teeth. In contrast, the maxillary cheek teeth have angles of circa 15° rostrally, but, their angles decrease to circa 10° more caudally.¹⁰

In brachydont teeth, the mesial (rostral) age-related drift (movement) of teeth is also influenced by normal masticatory pressures and both processes help keep the occlusal aspect of brachydont teeth in close contact. A similar rostral drift of cheek teeth also occurs in horses, but this can only extend as far as the Triadan 06 (first cheek tooth) whose clinical crown is angled caudally. The very complex movements of the temporomandibular joint (TMJ) have been well studied in humans,¹¹ but not fully in horses,¹² and the orthodontic forces the equine TMJ creates on equine dental drift is poorly understood. Pressure from the mesial (towards the midline) angulation of the Triadan 03s (corner incisors) similarly keeps the occlusal aspects of all six incisors in close contact with each other (and thus preventing incisor diastema formation) in most horses until old age.

Summary of Evolutionary Adaptations of Equine Teeth

- Great increase in tooth length
- Prolonged eruption of teeth
- Presence of cementum on clinical crown
- Protruding enamel ridges on occlusal surface
- Exposed dentine on the occlusal surface
- Exposed cementum on the occlusal surface
- Varying occlusal angles in different cheek teeth positions
- Development of infundibulae to increase occlusal enamel folds
- Maxillary cheek teeth rows further apart than mandibular rows
- First premolar (wolf teeth) is vestigial or absent
- Canine teeth absent or vestigial in females

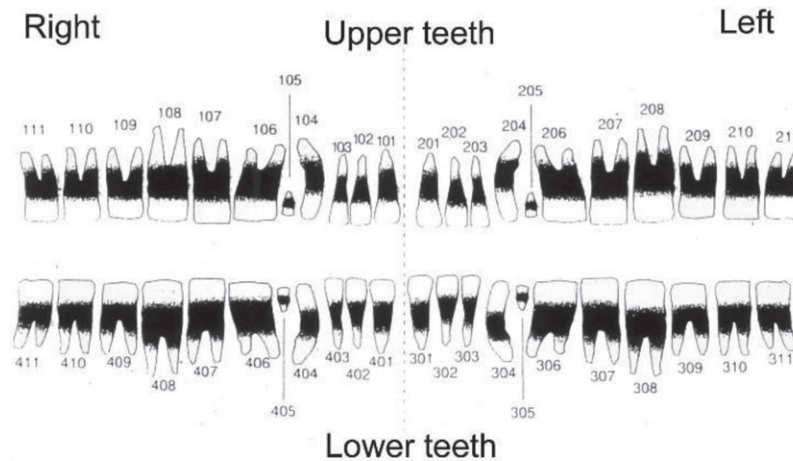


Fig. 5. The Triadan system of dental nomenclature. The teeth are divided into four quadrants, beginning in the right maxilla (quadrant 1), moving anticlockwise to the left maxilla (quadrant 2) to the left mandible (quadrant 3) and right mandible (quadrant 4). With deciduous teeth, four is added to these prefixes (i.e., are quadrants 5 to 8).

The Triadan system of dental nomenclature is now standard in equine dentistry. The teeth in each quadrant are numbered from rostrally i.e., Triadan 1 (central incisor) to caudally i.e., Triadan 11 (sixth or caudal cheek tooth; third molar) and these numerals comprise the last two digits of this system. The quadrants; right maxillary, left maxillary, left mandibular, and right mandibular, labeled 1 to 4, respectively (Fig. 5), are the first digit of the system. For example, the left maxillary central incisor is termed Triadan 201 and the right mandibular sixth cheek tooth (third molar) is Triadan 411. Deciduous teeth have 4 added to their first digit, thus the right central deciduous incisor is Triadan 501 (that is replaced at approximately 2.5 years of age by Triadan 101).

Dental Tissues

Enamel

Enamel, the hardest of all body tissues, is composed of 96% hydroxyapatite crystals and just 4% organic components, mainly proteins. The ameloblasts that form enamel die when the tooth erupts, consequently it is thereafter essentially a dead tissue and consequently cannot repair itself if it becomes damaged. The complete enamel content of teeth has been laid down when the tooth erupts and enamel content progressively decreases over time with dental wear. Little enamel may be present in the clinical crowns of some larger breeds of horses over 25 years of age, with the remaining clinical and reserve crown being entirely composed of cementum and dentine i.e., *smooth mouth*.⁷

Horses evolved two main types of enamel that can only be identified at the sub-microscopic level (by electron microscopy).¹³ These include Equine Type-1 enamel, which is composed of alternate parallel sheets and rows of hydroxyapatite columns. This type of enamel is extremely hard and is the main

type of enamel present in the cheek teeth (especially maxillary cheek teeth), which undergo prolonged high levels of masticatory forces. The second main type of equine enamel is Equine Type-2 enamel, which only contains enamel prisms, that are oriented (spaghetti-like) in all three planes and thus is very resistant to fracture, although it is softer than Type-1 enamel. These properties make it ideal for equine incisors, which undergo massive shearing stresses when prehending food, but experience much less occlusal wear than cheek teeth that are involved in prolonged, high-pressure mastication. It may be no coincidence that cheek teeth, although containing structurally harder enamel, undergo more spontaneous, termed “*idiopathic fractures*”¹⁴ than do incisors.^{15,16} Structurally, the equine enamel layers are thickest parallel to the long axis of the jaw and thinnest where they invaginate into the tooth.¹⁷

Cementum

Cementum, the softest of three calcified dental tissues contains approximately 50% organic components including collagen, and water. It is attached to enamel at the *amelocemental junction* both at the tooth periphery and also in the enamel-lined infundibulae of the incisors and maxillary cheek teeth. Infundibular cemental development or *cementogenesis* by *cementoblasts* begins at the periphery of the infundibulae and proceeds centrally toward the central vascular channel that runs the length of the infundibulum. This process occurs prior to eruption (nourished by vasculature on the occlusal aspect of the dental sac) and for some months after eruption of the tooth (from small rostral and caudal subgingival vasculature).¹⁸

In brachyodont teeth, all the cementum (cement) lies subgingivally and covers the root dentine where it acts as an anchoring point for the periodontal ligaments. As noted, cementum also covers the peripheral enamel of the entire crown in modern



Fig. 6. These images of mandibular cheek teeth show a very thick layer of peripheral cementum, which is an integral structural component of such teeth. Cementum is much softer than the adjacent enamel whose ridges protrude above it. Note also, the recessed dentine on the occlusal surface. Note the fissure fracture in the first pulp of the left tooth (arrow), these are generally innocuous lesions.

equids, where subgingivally, it contains the attachments of the periodontal ligament. Additional peripheral cementum is deposited on the reserve crown once it erupts from the confines of the alveolus (Fig. 6) and so peripheral cementum is much thicker in the clinical crown compared with the reserve crown.¹⁹ Cementum has a major structural role in the clinical crown, including acting in conjunction with the also flexible dentine, to form a sandwich on both sides of the hard but brittle enamel, forming a “biological safety glass” to prevent enamel fractures. Viable cementoblasts are found in high concentration within the more vascular gingival region and they can extend several millimeters occlusally on the clinical crown.¹⁹ Although the cementum covering the subgingival crown is an active connective tissue with a vascular supply from the periodontal ligament, some millimetres above the gingival margin, the cementum becomes an inert tissue following loss of its vascular supply.^{5,19} Once the tooth erupts, no further cementum can be deposited onto the clinical crown. However, subgingival cementum (the most reactive of calcified dental tissues) can be laid down in large quantities on the reserve crown or roots following chronic dental infection or trauma.²⁰

In any case, due to the prolonged eruption of equine teeth, the subgingival aspect of the crown (reserve crown) that is covered in cementum eventually erupts and becomes part of the clinical crown.

Dentine

Dentine, an elastic, avascular calcified tissue is the main structural component of teeth and along with peripheral cementum supports the surrounding, much harder but brittle enamel. Dentine is composed of approximately 70% mineralized tissue with 30% organic content, mainly collagen and water.²¹ *Odontoblasts*, which produce *predentine* that later becomes dentine, line the walls of the pulp horns and

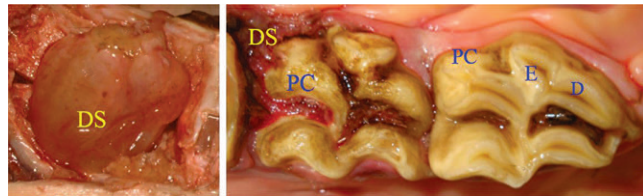


Fig. 7. This figure shows the later stages of development of maxillary cheek teeth. The image on the left shows an unerupted tooth within its gelatinous dental sac (DS). Centrally, there is a recently erupted maxillary cheek tooth with remnants of the DS still present. The primary occlusal surface of this hypsodont tooth is covered in peripheral cementum (PC) overlying enamel (the latter not visible). On the right is a maxillary cheek tooth that is in wear, i.e., has a permanent hypsodont occlusal surface with exposed layers of PC enamel (E) and both primary and secondary (darker stained) dentine (D).

have long *cytoplasmic processes* that extend from predentine into the dentinal tubules across the full width of dentine. These cytoplasmic processes elongate throughout life as secondary dentine is laid down and the odontoblasts move more centrally in the decreasing-sized pulp horns. This intimate relationship between odontoblasts that line the pulp and their cytoplasmic processes extending throughout dentine creates a single functional unit termed the *pulpdentine (pulpodentinal) complex* that makes dentine a sensitive and vital tissue, capable of repairing itself.²¹

In brachydont teeth such as humans, dentine is fully covered by enamel on the clinical crown and by cementum sub-gingivally, over the root dentine. Because of the prolonged eruption of equine teeth, the overlying cementum and enamel present on the occlusal surface at the time of eruption soon becomes worn away (Fig. 7), exposing the dentine that was present pre-eruption (termed *primary dentine*), that in turn becomes gradually worn away by normal mastication. In brachydont species, where dentine is very sensitive, dentinal exposure can cause great pain, but for unclear reasons this does not occur in normal equine teeth. The surface of occlusal dentine has apparently insensitive odontoblast processes protruding from it that are not stimulated by normal masticatory forces.¹⁷ However, the misuse, i.e., the overuse of motorized dental equipment to float (*perform odontoplasty*) the occlusal surface of cheek teeth, has clinically shown that dentine with apparently sensitive odontoblast processes is present below the insensitive occlusal layer. Kempson and colleagues²² showed severe occlusal dentinal damage, even with use of hand floats, following excessive odontoplasty (over-floating; Fig. 8). Such mistreated horses may immediately develop anorexia, quidding, and biting problems that may remain for weeks.²³ Such mistreated cases are sometimes alleged to have TMJ pain caused by having their mouth opened by a speculum for some minutes! On that spurious basis, all horses having general anaesthesia would have TMJ pain from hav-



Fig. 8. This image shows the left mandibular cheek teeth of a horse that has been grossly over-floated (excessive odontoplasty). Such cases can have exposure of sensitive dentine (or even of pulp) on the occlusal surface and therefore may show signs of oral discomfort after such mistreatment.

ing their mouth open for much longer periods, but this has not been recognized.

As equine teeth erupt, the subocclusal primary dentine overlying the pulp horns becomes worn away in normal attrition by masticatory forces. If it was not replaced, the underlying pulp cavity would eventually become exposed and possibly lead to death of the tooth from chronic food and bacterial contamination. The mechanism to prevent this scenario is the constant laying down of *secondary dentine* on the subocclusal aspects, as well as on the walls of the pulp horns. Secondary dentine is less mineralised than primary dentine and so absorbs dietary pigments and becomes darker than the adjacent primary dentine on the occlusal surface. This discoloration of secondary dentine is very obvious on incisors as the “dental star” that is used (with quite limited accuracy) to age horses. The cheek teeth contain five pulp horns in the four central (rectangular/square shaped) teeth and six in the (triangular shaped) first and last cheek teeth (Triadan 06s and 11s), except for the upper 11s that have seven pulp horns (Fig. 9). The initial equine secondary dentine that is deposited around the circumference of the pulp horn has a regular structure²⁴ later, toward the centre of the pulp horn before it becomes fully occluded, secondary dentine becomes quite unstructured and is termed *irregular secondary dentine*.²⁵ This equine irregular secondary dentine resembles *tertiary dentine* of other species, i.e., the type of dentine laid down in response to pulpar insult (such as occurs in response to overlying enamel caries in humans or a dental fracture with pulp exposure in horses).^{20,21,26}

Tertiary dentine can be either *reactive or reparative dentine*, which is produced from existing odontoblasts and undifferentiated mesenchymal pulpal

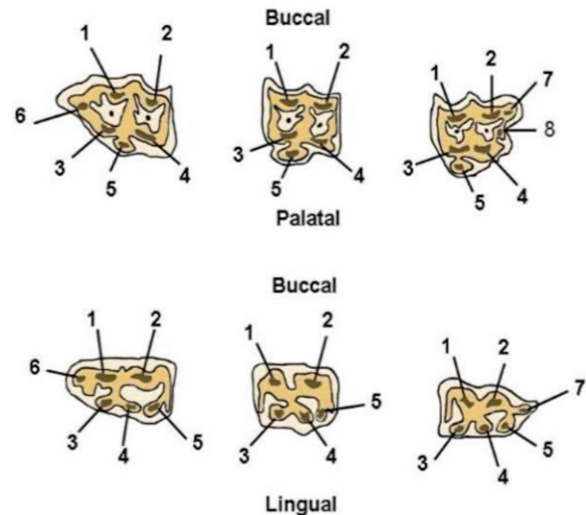


Fig. 9. Equine cheek teeth pulp numbering system of du Toit et al⁵ with maxillary teeth in the top row and mandibular teeth in the bottom row. The teeth on left are the 06s, the central teeth represent the 07s to 10s and the 11s are represented on the right. The four central teeth in each arcade contain five pulps, with additional pulps in the (triangular shaped) Triadan 06s and 11s. In each tooth the pulp numbering begins on the buccal aspect, from rostral (mesial) to caudal (distal).

cells, respectively. Tertiary dentine lacks much of the normal cellular structure of primary or regular secondary dentine, and essentially acts as a physical barrier to seal the pulp off from the noxious stimuli and prevents further damage.^{21,26}

Pulp

Dental pulp is a soft, sensitive, vascular connective tissue contained within pulp horns. It contains collagen, mesenchymal cells, nerves, lymphatics, and blood vessels that serve as the nutrient source for the odontoblasts and thus for dentine.²¹ The interconnections between these pulp horns and roots (the endodontic system) in equine cheek teeth are complex and age related,^{27,28} and knowledge of this *endodontic* (dental pulp related) anatomy is of great importance for endodontic therapy of equine teeth, which is increasingly performed.

All equine cheek-teeth pulp horns may communicate via a common pulp chamber for up to 9 years post-eruption in maxillary cheek teeth and 15 years post-eruption in mandibular cheek teeth, although the common pulp chamber typically begins to divide by 5 years of dental age.²⁸ The number of interpulpal communications also decreases as the horse ages, although there is much variability in the conformation of the segmental pulp chambers.²⁸ Mandibular cheek teeth typically contain a rostral (mesial) and a caudal (distal) root, with the rostrally and caudally located pulp horns eventually dividing between these roots, with some variation. Maxillary cheek teeth have one palatal (medial) and two buccal (lateral; rostral and caudal) roots. The in-

terpulpal communications within maxillary cheek teeth are more complex and varied than those in the mandibular cheek teeth; a common pulp chamber is maintained more frequently, but occasionally it divides into rostral and caudal segments.²⁸ Increasing age in the horse is associated with decreased pulp volume and extension of the pulp apically within the tooth.²⁸ The incisors, canine, and first premolars all have a single pulp canal (in young incisors it is divided into two parts occlusally by the infundibulum) and all have a single root.

Periodontal Tissues

The primary purpose of the periodontal structures is to flexibly attach the tooth to the bones of the jaws and allow for dental eruption. Gingiva, a firm mucous membrane surrounding the erupted tooth, is one of the four periodontal tissues. The gingiva, physically (by its attachment to the peripheral cementum by the marginal epithelium) and immunologically protect the underlying periodontal membrane (ligaments) from the oral environment that contains multiple species of bacteria, that would be pathogenic if they gained entry to the periodontal membranes. The gingival sulcus is a shallow depression (<5 mm deep in normal horses) between the gingiva and the clinical crown that becomes deeper with periodontal disease. The periodontal ligament, which lies between the tooth and alveolar bone, contains fibroblasts along with collagen fibers. Large bundles of these collagen fibers, termed *Sharpey's fibres*, connect the peripheral cementum to the alveolus and so flexibly attach and allow the prolonged eruption of the tooth. Distinct features of equine collagen fibers that allow them to resist the prolonged high-pressure vertical and lateral forces of mastication and also allow prolonged eruption have recently been described by Staszuk and colleagues.²⁹ Periodontal tissues contain extensive vasculature to nourish it and the adjacent cementum and bone (inner layer of capillaries) and also has specialized venules (with blind vessels and ampullae but without venous valves) more peripherally and deep in the alveolus to act as shock absorbers during mastication. These vessels prevent excessive tooth movement and so protect the pulpar vasculature.^{30,31} The periodontal ligament also provides sensory information via mechanoreceptors regarding movement of the tooth within the alveolus and on the hardness of objects being bitten.

The alveolar process, or the *lamina dura (denta)* as detected radiographically (but often not identifiable on computed tomography), is a thin dense layer of alveolar bone that contains the teeth that overlies the spongy, basal bone of the jaws. This area of alveolar bone may sequestrate following loss of its blood supply from trauma associated with dental extraction. If a tooth is lost, the alveolar bone will degrade over time and become



Fig. 10. A jointed iron snaffle bit from Greece circa 500 BC.

spongy bone, indistinguishable from the remaining bones of the jaws.

Domestication of the Horse

Some of the earlier records of human contact with horses come from the Palaeolithic period (circa 40,000 BC) from the El Castillo cave paintings in Spain and later from cave paintings in Lascaux, France (circa 28,000 BC) which show Przewalski-like horses being hunted for food. Smaller numbers of equine skeletons that had evidence of being butchered for food were found at human settlements from around these periods and from a later period, tens of thousands of equine skeletons were found at sites in France where horses were driven over cliffs during their migrations.

Prior to the domestication of horses a person could travel very limited distances (e.g., some tens of kilometers per day) and carry limited loads (e.g., 50 kg). With domestication of horses, considerably longer distances could be travelled at much greater speeds and carrying much greater loads thus allowing humans to more freely and quickly travel long distances for trade and communications (and unfortunately war). The development of equine domestication is claimed to have been one of the major steps in the socioeconomic development of primitive humans.^{32,33} There is still some debate as to when the horse was first domesticated, but current evidence suggests that it occurred circa 5000 years ago (3000 BC) in an area which is now in the Ukraine. From a veterinary dental viewpoint, it is interesting that much of the scientific evidence for the first domestication of horses is dental related, i.e., from bit wear found in equine skulls, particularly from a ritual burial site where a horse and chariot were buried in Dereivka (Kazakhstan). The equine skulls at this site had erosions, up to 3 mm deep, on the rostral aspect of the lower front cheek teeth (306, 406) caused by bits; and remnants of bits made from deer horn have been found in these settlements.^{33,34} Iron bits were used after the iron age (Fig. 10). An

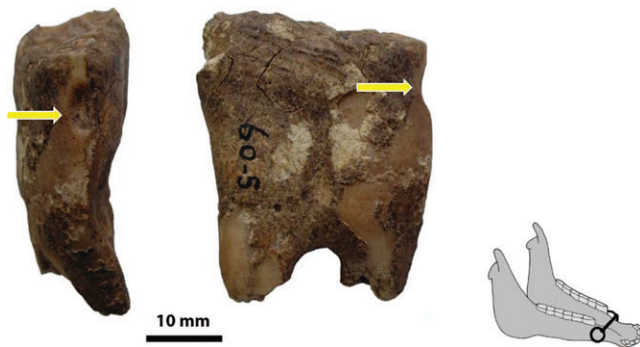


Fig. 11. Rostral (left image) and lateral (right image) views of a mandibular 06 from an iron age horse (radiocarbon dated to between 40 BC and AD 121) from Newgrange in Ireland showing grooves caused by bit contact (arrows). Details of this find published by Bendrey R, Thorpe N, Outram A, et al. The origins of domestic horses in north-west Europe: New direct dates on the horses of Newgrange, Ireland. *Proceedings of the Prehistoric Society* 2013;79:91–103. (Image courtesy of Robin Bendrey)

example of bit wear from a horse following this time is shown in Fig. 11.

The massive advantages that horses brought to mankind is manifested by the immense increase in the numbers of equine skeletons found in archaeological excavations of human settlements after domestication, in contrast with previously where they were scarce and showed evidence of butchering. Chemical analysis of pottery utensils also shows that mares were milked for food at these early settlements.³³ The contribution of horses to the transport of goods, rapid communications, agriculture, and military purposes at that time were enormous. The domesticated horses spread widely to all of Europe, the Middle East, and Asia. Very mobile armies such as those of Genghis Khan that had tens of thousands of horses, mainly owed their “success” in conquering other civilizations to their horses. Later civilizations also used horses in sports such as chariot racing in Greece and Rome. Later, with advances in agriculture, horses played a major role in agriculture, both tilling the soil and harvesting; in forestry, and at the beginning of the industrial revolution, in transporting freight on carts, and in towing barges along canals. Horse coaches were the mainstay of local and long-distance transport and mail communications also during this period, with teams of coach horses changed frequently to speed up communication links. During this period, many equine sport disciplines developed and many different breeds of horses were created (including Thoroughbreds for racing), but the mainstay of horse work was for carriage and farm work. Because of the enormous economic importance of horses, veterinary studies in the 1700s, 1800s, and early 1900s concentrated on this species, as later discussed.

The development and rapid widespread use of trains decreased the need for horses for long-distance transport or mail delivery and the development of steam

engines in barges soon replaced the use of horses for pulling barges. Horses were still needed in agriculture, forestry, and as carriage horses and for goods transport within cities, with 500,000 working horses in London alone in 1906.³⁵

In the beginning of the twentieth century, the advent of the internal combustion engine caused the main decline in working horse numbers, with cars and lorries replacing horses in cities, and the tractor gradually replacing the horse in agriculture in all but the smallest farms in Western countries. Horse numbers greatly decreased throughout the twentieth century up until the 1950s. Simultaneously, equine veterinary studies, which until the early 1900s was the backbone of veterinary education because of the pre-eminence of the horse, was neglected, with veterinarians now largely concentrating on farm animal medicine, before switching to its current emphasis on small-animal studies.

In Western countries, horses have made a large resurgence during the last 30 to 40 years, now primarily for sport and recreation. Thankfully, there has been a parallel increase in equine veterinary scientific studies during this time, although scientific studies in equine dentistry have lagged behind small-animal dental studies.³⁶

Early Veterinary Dentistry

There is written evidence from ancient Babylon (circa 2200 BC) of veterinary treatments, and later from the works of Aristotle in Greece circa 500 BC and later from Roman authors including Chiron and Vegetius, the latter whose treaty on equine veterinary care was translated into English in 1528.³⁷ These latter authors described some disorders of the equine teeth and jaws. However, as was the case with human treatments of that era, many (most) equine treatments including blood letting, blistering of skin overlying “diseased” areas, firing and cauterizing, and administering powerful purgatives were of no medical value and were in fact, painful and harmful to the patient. It is amazing how such obviously harmful “remedies” continued to be used in both human and veterinary medicine even within the last 100 years. These treatments probably remained popular because they demonstrated the “power” of the clinician by inducing visible although likely harmful effects such as by causing large blisters where irritant cantharides (poisonous, blistering preparation made from the bodies of a beetle) pastes were applied. There is little evidence of veterinary texts from Europe during the middle ages, but the Arabic literature on equestrianism flourished at this time.³⁷

Little significant advances in equine dental knowledge or treatment occurred until the 1700s with the advent of the age of enlightenment and the parallel scientific revolution. During this time, academic veterinary colleges were developed, initially in France, later in Britain, and the first US Veterinary College opening in 1875.³⁷ Some advances in

equine dental treatments, including in the removal of large dental overgrowths, treating sinusitis, and extracting teeth (exodontia) were made in the 1700s.

During the late 1800s when the importance of the horse in transport, agriculture, industry, and leisure was still near its peak, more significant advances were made in equine veterinary studies, such as in equine anatomy and physiology and to a much lesser extent in dentistry. Notable quotes from UK veterinary texts of that time including from William Dick, the founder of Edinburgh Veterinary School, was "The disease of the teeth attracting attention are but few."³⁸

Fortunately, some Continental and American veterinary surgeons were more interested in equine dentistry and in the late 1800s, some innovative equine dental instruments were made by German veterinary surgeons including Hauptner and Gunther, and by Hausmann and McPherson in North America. Some of these excellent designed instruments are still in use.³⁷ Equine dental textbooks, including a seminal work by William Clarke³⁹ were published in the late 1800s and Merrillat's seminal equine dentistry text was published in the United States in 1916.⁴⁰ At last, there was increasing use of rational, scientific-based dental treatments, and the rejection of many inhumane and nonvalidated treatments such as bloodletting, blistering, administering strong purgatives, burning "lampas lesions" (physiological engorgement of the hard palate in young horses) with hot irons, although the persistent use of hot irons to treat strained equine tendons by some veterinarians in the current century remains unfathomable. Treatments utilized in the late 1800s included oral extraction of cheek teeth in cast horses and removal of overgrowths by mechanical dental shears. Knowledge of sinusitis treatments including trephination and lavage had actually been documented in French textbooks since the early 1700s. Merrillat did not believe in some of the quackery performed at that time such as incisor reductions "to prevent them from keeping the cheek teeth out of contact" but stated "*It was easier to trim the incisors and collect fees than to give a lecture on anatomy without pay.*"⁴¹

Colyer, a professor of human dentistry in London, performed some important dental surveys on working horses in London in the early 1900s. These showed a high prevalence of periodontal disease that he attributed to the coarse foodstuffs he found embedded in periodontal pockets of affected horses.³⁵ However, examination of images of some of his preserved specimens⁴² show that cheek-teeth diastemata were in fact the actual cause of this periodontal disease.⁴³

In the 1930s a large body of scientific knowledge was amassed by German veterinarians, in particular by Ernest Becker, who performed disease-prevalence surveys and gross pathological studies on equine dental disorders. He also developed the first mechanized equine floats.³⁷ In contrast, for much of the mid-to-late 1900s the English-speaking world virtually ig-

nored equine dental research (along with most other equine veterinary research). Clinical dentistry was also largely ignored by the veterinary profession, except for extraction of apically infected teeth and treating dental fractures and major dental overgrowths, all conditions that did not respond to medical treatments and were of such serious concern that they could not be ignored by the owner and thus by the owner's veterinarian.

The improved economic situation worldwide in the second half of the twentieth century led to a resurgence of interest in equestrian sports. This in turn led to a revival of equine veterinary interest and resulted in the founding of fully equine veterinary bodies including the American Association of Equine Practitioners (AAEP) and the British Equine Veterinary Association (BEVA) in the 1960s. These organizations promoted a major revival in equine veterinary interest with a critical scientific basis. Subsequently, in the 1970s and 1980s there were major scientific and clinical developments in many equine specialities, especially in the orthopaedic, respiratory, and reproduction fields. In contrast, with the exception of a handful of authors including Hofmeyer in South Africa,⁴⁴ Honma et al⁴⁵ in Japan, and Baker^{46,47} in Britain who performed studies on equine dental anatomy and infundibular caries in the 1970s. Minimal scientific advances were made in equine dentistry between the 1940s and the 1990s. During this period, university curricula largely ignored equine dentistry or poorly taught it, perhaps giving a single lecture on cheek-teeth repulsion, as was the case in the author's veterinary school.

More recently, there has been a significant revival in scientific equine dental studies including gross pathological studies by Wafa⁴⁸ in Ireland. Walmsley in the United Kingdom was the first author to critically examine the ageing of horses by incisor examination and showed its inaccuracy⁴⁹ and Kilic and coworkers^{13,17,24,50} in Scotland performed detailed histological and ultrastructural studies of the normal equine calcified dental structures. Peter Rosedale, the eminent editor of the Equine Veterinary Journal (EVJ), with his usual foresight also recognized this deficiency in equine dental studies and in 1993, devoted an issue of EVJ's sister journal, Equine Veterinary Education (EVE), to equine dentistry that contained an editorial, "Equine dental disease—A neglected field of study."⁵¹ This edition contained original scientific papers on this topic, that encouraged other veterinarians to research and report on equine dentistry. Since then, clinical and scientific equid (equine and donkey) dentistry has had a major renaissance worldwide, with very many scientific studies coming from Europe including from Drs. Dacre and du Toit^{5,16,25,26,52-55} in Edinburgh, Dr. Vlaminck in Belgium, Drs. Staszuk, Bienert, and colleagues in Germany,^{8,28-31} Dr. Simhofer in Austria, clinical research articles from the author's clinic,^{14,43,56,57} Dr. Tremaine

in the United Kingdom, and more recently, clinical research from North American authors including Drs. Easley, Carmalt, Rawlinson, Earley, Baratt, and Galloway. Currently, many quality scientific articles are being published in different eminent journals worldwide that will be briefly discussed. However, it is regretful that with a few exceptions, American universities have not been as proactive in equine dental research as their European counterparts.

In the 1970s and 1980s when the revival of scientific veterinary interest of horses was well underway, equine clinical dentistry was ignored or performed badly, and during this period lay persons, often terming themselves “equine dentists” filled this vacuum. This period coincided with the development of motorized dental instruments and many aggressive, nonvalidated dental treatments were revived or “developed” during this time, mainly by lay persons but also by some veterinarians. These included reductions (odontoplasty) of incisor and canine teeth, removal of normal transverse ridges, “bit seating,” and “performance floating” (the latter often a euphemism for excessive floating) that were detrimental to the horse and a summary of some of these alleged “Well Known Facts on Equine Dentistry” are presented in the textbox below.

Well Known “Facts” on Equine Dentistry (All Untrue!)

- Incisors should be regularly reduced (floated) to “increase molar contact”
 - Canine teeth should be reduced “to prevent injury to operator’s hands”
 - All ridden horses should have good bit seats “for their biting comfort”
 - All wolf teeth must be extracted “as they always cause biting (and multiple other) problems”
 - All transverse ridges should be removed “to promote rostral mandibular movement”
 - Any size of dental overgrowth can be reduced in a single procedure without risk of pulpar exposure
 - All upper and lower cheek teeth occlusal angles should be floated to “their normal angle of 15 degrees”
 - Older horses have thick subocclusal secondary dentine and so “there is never any risk of pulpar exposure in this age group”.
 - Horses that start quidding following routine dental treatment “have strained temporomandibular joints (TMJs)”
-

For a short while, some American veterinarians also adopted these nonvalidated procedures, that were only based on pseudoscience.

In the 1990s both BEVA and AAEP recognized the major deficiency in their members’ equine dentistry knowledge and practical skills and subsequently began very active programmes to educate their members on current equine dental scientific knowledge and also update their clinical dentistry techniques. Since 1998, more than 2000 BEVA members have attended practical courses on equine dentistry with tremendous input initially from American colleagues such as Jack Easley and Leon Scrutchfield.

Likewise, AAEP has run numerous practical courses and major “Focus” conferences devoted to equine dentistry. With advances in scientific anatomical and pathological equine dental studies, publication of some evidence-based equine dental treatment studies and great efforts by national equine organizations, especially in the United States, Canada, Sweden, United Kingdom, Germany, and Australia to support theoretical and practical aspects of this discipline, most or all of the aggressive dentistry techniques have now been discarded by veterinarians. Many national equine associations now also run conferences, day meetings, and practicals. The development of specialist equine sections of the American (AVDC) and European (EVDC) Veterinary Dental Colleges in 2013 with great help from Colin Harvey (a small-animal veterinary dentist) has been a major achievement. The development of these Colleges has standardized and greatly raised clinical standards and is allowing formal equine residencies to be run. Currently we are fortunate that equine dentistry is practiced to a very high standard in many countries by very many equine veterinarians.

2. A Review of Current Equine Dentistry

Examination of Equine Teeth

Palpation through the cheeks may reveal food pocketing or major cheek-teeth irregularities (such as a missing tooth or buccal dental fragment, a buccally displaced dental fragment or large overgrowth) of the cheek teeth, particularly of the rostral cheek teeth. Even if no abnormality is palpable externally, the presence of pain during cheek palpation may suggest the presence of buccal ulceration, most commonly due to sharp enamel overgrowths on the buccal aspect of the upper cheek teeth. When eating forage, horses with dental pain may not make the normal vigorous crunching sounds and/or may show restricted mandibular movements that may be confined to one side of the mouth, or they may quid (drop unmasticated food from the mouth).

Equine dental examination is best performed under sedation, except perhaps, for some asymptomatic racehorses undergoing routine (especially repeat) dental examinations, when sedation could interfere with racing schedules. A competent equine oral examination can only be performed using a full-mouth speculum (gag), but incisor examination should be systematically performed prior to placement of the speculum. The equine incisors and canine teeth are readily examined, and thus even minor disorders of these teeth are readily detected, including by owners. With the mouth closed, and while stabilizing the head, the mandible should be moved sideways and the amount of sideways movement prior to separation of the incisors (as the angled occlusal surfaces of opposing cheek teeth come into contact) should be assessed. Any sudden obstruction to this lateral movement (such

as caused by large cheek-teeth overgrowths) should be noted. There is much variation in the degree of incisor lateral movement before the incisors separate in normal horses, that is dependent on their jaw anatomy and their variable cheek-teeth occlusal angles.¹⁰

A more complete incisor and canine teeth examination can be performed with a plastic pipe placed in the bars of the mouth. The occlusal surfaces of the upper incisors are best examined with a dental mirror or oral endoscope, unless the examiner is very mobile! Due to a combination of oral anatomical features of herbivores, including limited opening of the mouth, rostral positioning of the lip commissures, and the great length of their cheek-teeth rows, it is not possible to visually examine all of the equine cheek teeth (especially the caudal mandibular cheek teeth), unless the examiner uses an equine dental mirror and headlight or an oral endoscope. Major problems, especially of the caudal mandibular cheek teeth and their gingiva, and all buccal areas can readily be missed unless all aspects of the teeth and adjacent gingiva are carefully visually examined and palpated. It is also useful to smell one's gloved hand after oral examination for the presence of malodor, which usually suggests anaerobic infections, such as diastema-induced periodontal disease, fractures, or advanced dental caries (infection of the mineralized components of teeth) are present.

In addition to performing a thorough dental examination it is essential that the findings of the examination are accurately recorded in a standardized manner on equine dental charts, such as those supplied by national equine organizations such as AAEP or BEVA. In addition to their professional value, for example in monitoring the progress of dental disorders, copies of these charts given to clients can emphasize the quality of dental care their horses are receiving and also act as reminders for revisits.

Most of the equine tooth lies subgingivally and so cannot be visually examined. Consequently, imaging is required to assess disorders involving the reserve crown and roots, such as apical infections and resorptive lesions. Radiography is the standard equine imaging modality, but it has limitations, particularly in early cases of suspected apical infection, where subtle dental changes combined with superimposed adjacent structures often makes accurate radiographic diagnosis difficult. With advances in technology, including the advent of standing equine computed tomography systems, that will no doubt decrease in price and increase in quality over the coming years, such advanced three-dimensional imaging techniques will become commonplace in the future and allow a more accurate diagnosis of many equine dental disorders. Equine dental imaging including radiography and advanced imaging have recently been well reviewed.^{58,59}

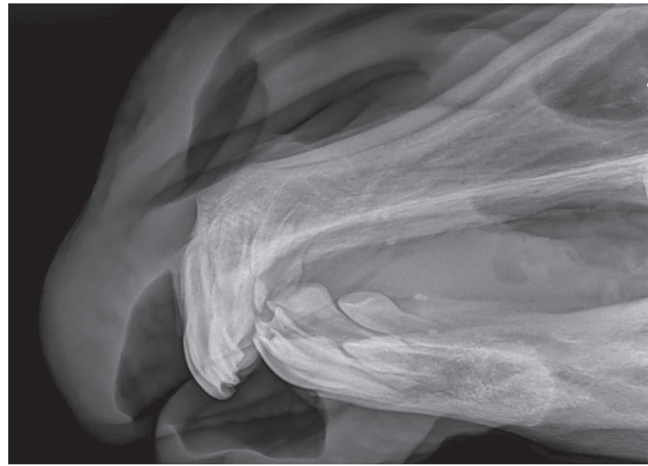


Fig. 12. Lateral radiographs of a 6-month-old foal with overbite. At this stage, placement of a tension band orthodontic device between the upper incisors and the maxillary cheek teeth would worsen the disorder, by bending the incisive and maxillary bones further ventrally.

Dental Disorders

Incisors

Overjet (upper incisors protruding rostral to lower incisors) or *overbite* (upper incisors protruding rostral to and also *directly in front* of lower incisors) are often interchangeably given the colloquial term of parrot mouth (Fig. 12). These are a cranio-facial skeletal disorder with secondary dental abnormalities and are hereditary to a varying degree. The upper incisors often develop overgrowths, most markedly of the O1s that gives them a “smile” appearance. Even marked anatomical incisor abnormalities seldom cause functional problems with prehension.^{60,61} The main clinical problem occurs later, with the development of focal, rostral upper O6, and caudal lower I1 cheek-teeth overgrowths in adult horses, that may become tall enough to cause soft-tissue lacerations and/or masticatory and biting problems. Potential treatments for overjet include placement of angulated “bite plates” on the upper incisors or orthodontic tension wires between the upper incisors and cheek teeth to retard growth of the upper jaw.⁶⁰ If overbite is present, orthodontic tension wires *and* bite plates are necessary. These treatments will substantially improve, but not fully correct most cases.⁶¹ Owners of affected foals should be prepared to accept that most foals will dislodge or break these orthodontic prostheses at least once, and that they need to be replaced, usually under general anaesthesia. More invasive, osteodistraction techniques that involve sectioning of both mandibles and insertion of expandable devices to elongate the mandibles have also been used for correcting overjet/overbite.⁶² All cases of overjet or overbite, treated or untreated, should have at least biannual dental assessments, during which the in-



Fig. 13. This 4-year-old pony has multiple developmental incisor abnormalities, including underjet, displacement and rotation of 302, displacement of 202, and also the acquired disorders of periodontal disease, and calculus deposition on 202.

cisors and cheek teeth can be assessed for overgrowths, that should be reduced in stages if large.

Underbite (“Sow Mouth”)

Underbite (prognathism, “sow mouth,” “monkey mouth,” “undershot jaw”) is also a primary craniofacial skeletal disorder with secondary dental abnormalities (Fig. 13). This disorder is uncommon in larger breeds of horses, but is common in donkeys, small ponies, and miniature horses. It is usually clinically insignificant unless there is total lack of occlusion between the upper and lower incisors. Severely affected equids will eventually develop a concave upper incisor occlusal surface, which has been termed a “frown” and these equidae will later develop

lower 06 and upper 11 overgrowths, that need assessment and treatment at least biannually.⁶⁰

Displaced Incisors

Most major incisor displacements involve the permanent incisors and are developmental in origin due to overcrowding of teeth or displacement of developing dental buds⁶³ (Fig. 14). Less commonly, they are caused by jaw trauma in foals with acquired displacement of the permanent incisor buds. If displaced incisors protrude at very abnormal angles, e.g., horizontal to the remaining incisors—they need to be extracted (Fig. 14). The periodontal ligaments in some of these displaced incisors may be weak, as they will not have had normal occlusal contact and *simple extraction* is possible. However, if firmly attached, a *surgical extraction* (raising a gingival flap over the reserve crown, and variable removal of alveolar wall) is usually necessary.⁶⁴ Lesser degrees of incisor displacement can be treated by placement of orthodontic tension wires anchored to adjacent incisors. Minor displacements may also be treated by regular floating of protruding areas (including by owners) for example, using a small diamond-coated “S” float.⁶⁵

Retained Deciduous Incisors

Deciduous incisors, which normally lie on the occlusal or labial aspects of their permanent counterparts, are occasionally retained beyond their normal time of shedding. This may be due to a misplaced permanent dental bud that does not develop beneath the deciduous and thus assist in the resorption and physical shedding of the deciduous tooth. When retained for a prolonged period, they will cause the erupting permanent incisor to be displaced further lingually/palatally (caudally) and may even cause permanent wear changes in the opposite incisors. Loose,

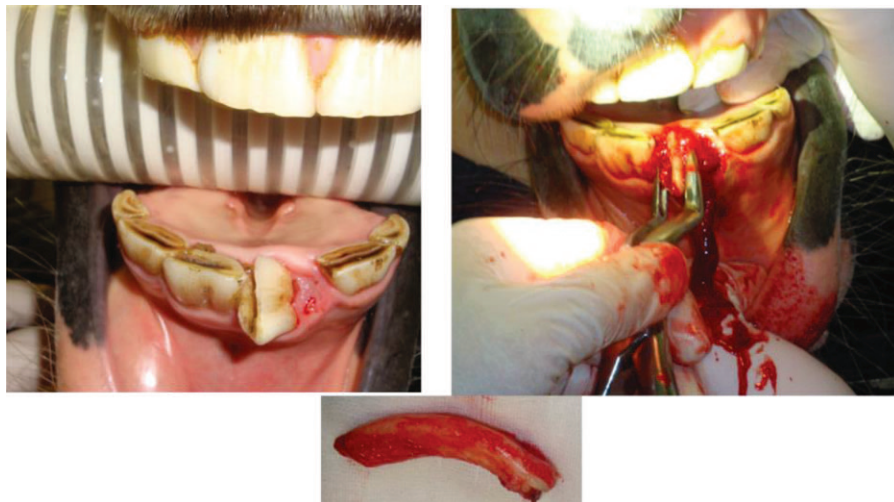


Fig. 14. This Triadan 301 has marked developmental displacement and rotation and consequently would continue to cause lip trauma until extracted. Although it had a long clinical crown and thus extensive periodontal ligaments, these attachments were not strong and with limited elevation (circa 10 mm) below the gingival margin, a simple non-surgical extraction was possible.



Fig. 15. The clinical crowns of 101, 102, and 103 of this horse have recently sustained complicated (i.e., with pulp exposure) fractures. Removal of the fracture fragments (right image) confirms these pulpar exposures and shows viable, bleeding pulps in all three pulp horns. With appropriate treatment (i.e., endodontic therapy) all of these teeth should survive, then erupt faster than usual due to lack of occlusal contact and eventually come into occlusion.

retained incisors can be removed using dental forceps. If more firmly attached, they will need to be extracted under sedation and local anaesthesia using a sharp dental luxator or scalpel to cut the strong gingival attachments and then elevators to fatigue their periodontal attachments. If it seems that the reserve crown is very long, a surgical extraction is required. It is most important that retained incisors are differentiated from supernumerary incisors. Rarely, retained deciduous teeth are displaced lingually/palatally, making their extraction difficult.

Supernumerary Incisors

Supernumerary incisors (i.e., permanent incisors that are additional to the normal six incisors on each arcade) can have very long (<7.0 cm) reserve crowns, that are often intimately interwoven between the reserve crowns and roots of the normal permanent incisors. In addition, given that supernumerary incisors are usually identical in appearance to the normal incisors (i.e., are termed *supplemental* teeth) they are usually impossible to visually or radiographically differentiate from normal incisors. Consequently, extraction of these supernumerary teeth is often both very difficult and also risks damaging the adjacent normal incisors. Exceptions are the presence of individual supernumerary incisors that protrude subgingivally—that can be more readily surgically extracted. As supernumerary incisor teeth usually cause little clinical problems unless grossly displaced, they are usually best left *in situ*, with biannual rasping of unopposed teeth to prevent overgrowths, or extraction, if marked periodontal disease later develops between/around them.

Incisor Fractures

Fractures of the incisor teeth and often of the supporting rostral mandibular or incisive (premaxillary) bones can occur due to trauma, usually from kicks but rarely “spontaneously” unlike cheek teeth. If a limited amount of calcified dental tissues are

fractured without any exposure of the pulp cavity—this is termed an *uncomplicated dental fracture*. Such fractured teeth are endodontically (pulpar tissues) healthy and will continue to be pain free and erupt normally. Any sharp edges present must be carefully floated to prevent lingual or labial lacerations. Unfortunately, incisor fractures more commonly result in exposure of the pulp horns (i.e., termed a *complicated dental fracture*) and bleeding will be seen on the occlusal surface from the exposed pulp (Fig. 15).⁶⁶

Pulpar exposure always results in pulpar inflammation and infection that are caused by pH changes due to contact with saliva, and by impaction of food and oral bacteria into the pulp horn. All young equine teeth have very wide apical foraminae (root canal openings), along with a very large and vascular pulp, which can often resist inflammation-induced ischemia. Consequently, pulp exposure, especially in younger horses, does not necessarily lead to deep pulpar infection and inflammation and subsequent ischemia with tooth death, as would occur with a similar pulp exposure in brachydont (e.g., human or canine) teeth. All incisor fracture cases should receive tetanus antitoxin and prolonged (7–10 days) antibiotic therapy (preferably antibiotics active against anaerobes). They should also receive non-steroidal anti-inflammatory drug (NSAID) therapy to reduce pulpar inflammation. Preferably, endodontic (root canal) treatment should be performed by a specialist veterinary surgeon to save the tooth.⁶⁴ Such endodontic treatment that once was rare is now regarded as a standard, successful procedure. An additional first-aid treatment that could be performed by general equine practitioners prior to referral is to apply local anaesthetic with adrenaline and then debride the exposed pulp with an 18-g needle to create a 5-mm deep cavity in pulp canal. Following haemostasis by cotton buds and lavage with 0.1% chlorhexidine, a semisolid calcium hydroxide paste can be placed into the overlying

pulp canal to act as a pulpar dressing. Calcium hydroxide is antibacterial due to its high pH and stimulates tertiary dentine formation. However, these calcium hydroxide pastes may be quickly lost in some cases, unless an additional overlying, more solid (usually UV light cured) layer is added.

Abnormalities of Incisor Wear

On full manual, lateral movement of the mandible with the horse's jaws closed, the incisors should separate. The degree of separation varies greatly between horses and as noted, incisor reductions to allow further incisor occlusal separation to unsubstantiated rigid dimensions is an unwarranted procedure. Irregularities of the occlusal surface of the incisors (or large overgrowths of the cheek teeth) will prevent or restrict this normal maneuver, usually unilaterally. Incisor disorders that restrict lateral jaw movement include overgrowths due to traumatic loss or maleruption (delayed eruption, displaced or other abnormalities of eruption) of an opposite incisor. Such cases should have overgrown areas sequentially (e.g., 3 mm at a time) reduced at 3-monthly intervals. The previously noted "smile" and "frown" incisor occlusal configurations that occur with overjet/overbite and underjet respectively, are generally best left alone unless soft tissue is being traumatized. Abnormal wear develops on the occlusal and labial aspects of the Triadan 01s (central) and sometimes of the Triadan 02s (middle incisors) in horses that crib-bite, wind-suck, or rub their incisors on fixed objects.

Diagonal Bite (Slant Mouth; Slope Mouth)

A minor degree of diagonal bite is present in a significant number of horses. This disorder was previously believed to be generally caused by unilateral, painful cheek-teeth disease, causing the horse to preferentially use the opposite side of its mouth for masticating, thus causing secondary incisor wear abnormalities. The perceived treatment was to mechanically level the incisors and float the cheek teeth to remove the "problem." A large study by DeLorey⁶⁷ showed that such incisor adjustments were seldom of value because the occlusal surface quickly reverted to the pre-treatment diagonal state. It is now accepted that most such incisor abnormalities are secondary to craniofacial bone abnormalities, primarily wry nose (lateral deviation of the nasal and incisive bones) but also due to other developmental abnormalities, including of the maxillary bones that can be appreciated by recognizing the unequal angles and heights of the vaults of the hard palate.⁶⁸

Diastema/Periodontal Disease

Incisors, like cheek teeth, taper in toward their apices and unless there is adequate rostral-medial (mesial) angulation of the 03s (corner incisors) to continually keep their occlusal surfaces in contact during age-related incisor eruption, spaces termed

diastema (plural *diastemata*) will develop in the *interdental* (*interproximal*) spaces that allow food trapping between the incisors. These diastemata are usually termed *valve diastemata* because they are narrower occlusally than at the gingival margin. Forage trapped in diastemata may get compressed into the gingiva causing gingivitis initially, and eventually becomes compressed more apically, damaging the three deeper periodontal tissues (periodontal membranes, peripheral cementum and alveoli) in periodontal disease. It can be difficult to remove matted impacted forage between incisors, which also accumulates on the palatal/lingual aspect of incisors. Widening the occlusal aspect of these diastemata to circa 3 mm wide, that will allow all impacted food to be removed, including from periodontal pockets, is a possible treatment. Treated diastemata (now termed *open diastemata*), because they are the same width at occlusal and gingival aspects, tend to trap food less. They also allow owners to clear entrapped food with a normal toothbrush to help prevent periodontal disease.

Equine Odontoclastic Tooth Resorption and Hypercementosis

This is a recently described, painful disorder of incisor and canine teeth of older horses, variably causing periodontitis, with resorptive and/or proliferative changes of all the calcified dental tissues.⁶⁹ Equine odontoclastic tooth resorption and hypercementosis (EOTRH) shares some features with similar dental syndromes in cats (feline resorptive syndrome) and in humans, except that some horses also develop a high degree of hypercementosis that can mask the initial resorptive lesions (Fig. 16). Allowing suspected cases to bite a carrot at different sites on its incisors will help identify painful teeth and radiography of suspect teeth is essential for complete evaluation of this disorder (Fig. 17). Horses with extensive hypercementosis can be recognized by the subgingival thickening of the incisor alveoli. These teeth are often very stable and pain free and so in the absence of periodontal disease, such cases do not need any treatment at this time. However, horses that develop more lytic lesions often develop fractures of teeth and if resorptive lesions develop near the gingival border, this will permit periodontal disease to develop.^{64,66} The presence of fractured teeth and periodontal disease can cause great pain and is a serious welfare problem for affected horses. Currently, there is no known treatment for EOTRH-affected teeth, and loose, fractured and painful teeth should be extracted. If multiple teeth on an arcade are affected, it may be preferable to surgically extract all six incisors together.⁶⁴ If just one or two incisors remain following exodontia of the remaining teeth, these teeth, now without any support from adjacent teeth, may quickly become loose.



Fig. 16. Upper incisors of an aged horse with EOTRH. There is calculus at the gingival margins, evidence of thickening of the reserve crowns, clinical crown fractures of 101 and 201; and most significantly, gingival recession and gross swelling over the alveolus of 202 that has a sinus tract.

Fibro-Osseous Mandibular Tumors

The rostral aspect of the mandible near the symphysis is a predilection site for the development of fibro-osseous growths in young horses. The precise

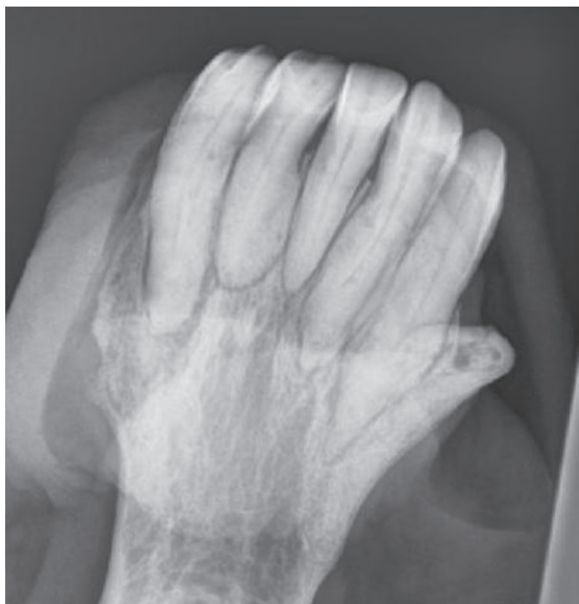


Fig. 17. This radiograph shows marked EOTRH of the mandibular canine teeth and all incisors. The canine teeth have more severe resorptive-type lesions whereas the incisors have more hypercementosis-type lesions, although hypercementosis could mask internal lytic lesions. These incisors with hypercementosis are stable and pain free and currently do not need any treatment. The grossly lytic canine teeth with secondary periodontal disease need to be extracted.

classification of these tumors as neoplasms or an equally destructive non-neoplastic growths can be problematic. Radical resection of the rostral mandible is a successful treatment with surprisingly minimal functional consequences to loss of the lower incisors.⁷⁰ Less commonly, more benign fibro-osseous lesions can affect the upper incisor region, but the treatment is similar, i.e., early radical resection of the affected area (Fig. 18).

Canine Teeth

Occasionally, one or more canine teeth will have delayed eruption, and the mucosa overlying such areas may be painful on palpation and delayed eruption of canine teeth may possibly be associated with biting problems (Fig. 19). Incision of the overlying mucosa and periosteum, i.e., *operculation*, may help the eruption of such teeth. Canine teeth, in particular the lower canine teeth, are the equine teeth most prone to calculus formation. This is for unclear reasons, possibly the absence of direct apposition of the upper and lower canine teeth, that would force fibrous forage over their surfaces and reduce organic plaque formation. This calculus commonly causes a local gingivitis but seldom involves the (three) deeper periodontal tissues. Canine calculus is readily removed with forceps and subgingival areas of calculus should then be carefully, fully curetted off. Owners should be advised to brush susceptible canine teeth with a toothbrush at least a few times weekly to prevent the initial buildup of organic plaque that will later calcify and form calculus.

Canine Teeth EOTRH

As well as affecting incisors, EOTRH also affects the canine teeth of older horses, sometimes severely (Fig. 17), and occasionally, without any obvious simultaneous clinical involvement of the incisors. This may be manifested as the presence of caries-like lesions or spontaneous fractures of canine teeth (possibly multiple canine teeth). Radiography will readily confirm its presence and severely affected teeth especially with erosive lesions on the clinical crown and periodontal disease need extraction. This invariably has to be a surgical extraction, given that even older horses may have >5 cm of the canine tooth reserve crown.

“Wolf Teeth” (Vestigial First Premolars)

There are no deciduous wolf teeth (Triadan 05, 1st premolar) and it is believed that most wolf teeth are lost when the permanent 06s erupt; consequently, yearlings more commonly have these teeth than adult horses. Wolf teeth are *blamed* for interfering with the bit and otherwise causing many behavioral problems in ridden horses, and on this basis these teeth are frequently extracted. Wolf teeth most commonly occur in the maxilla and lie in front of the 106/206. It is anatomically difficult to envisage how, if small and in a normal position, these teeth could



Fig. 18. The left image shows a large fibro-osseous growth of the incisive area of a pony, with subsequent loss of some and displacement of other upper incisors. Following radiography to confirm its nature and to determine surgical boundaries, the complete mass (and a 10-mm margin) was resected and the gingiva sutured with primary closure (middle image). There was no recurrence of the growth and the image on the right shows this horse 5 years later, having fully coped with loss of the upper incisors during this time.

interfere with the bit. In contrast, the rarely encountered mandibular wolf teeth can readily interfere with the bit. Some veterinarians use the argument that because these teeth never do any good and may occasionally cause problems, they should always be removed.

Although there is no objective evidence that normal-sized and positioned maxillary wolf teeth should be extracted, large, displaced or persistently unerupted wolf teeth can cause cheek or gingival trauma, from bit pressure and these teeth should be extracted in ridden horses (Fig. 20). Using local anesthesia and sedation, long, sharp, offset wolf-teeth elevators can effectively be used to cut the gingiva and

stress the periodontal ligament in a conventional manner before using forceps to extract these teeth.

Developmental Cheek-Teeth Disorders

Retained Deciduous Teeth

Retention of the remnants of the deciduous cheek teeth (“caps”) can occur in horses between 2 and 5 years of age. When very loose or just partially retained by gingival attachments, they may cause periodontal pain or soft-tissue lacerations. Affected horses may suddenly show quidding, playing with the bit, and occasionally, loss of appetite for a couple of days. Such signs of oral discomfort in young horses immediately warrant a careful examination of the rostral three cheek teeth for evidence of loose “caps” or caps with a distinct space between them and the underlying erupting cheek tooth. Food trapping between a retained cap and the underlying erupting tooth can induce deep occlusal caries of the latter that occasionally lead to pulpar and then to apical infection, even before this permanent tooth fully erupts. Retained caps should be removed using specialized “cap” forceps or a long, slim elevator.

The prolonged retention of caps has been alleged to cause delayed eruption of the underlying developing permanent tooth, thus causing the development of large “eruption cysts” (“3-year-old or 4-year-old bumps”) under their apices. The presence of enlarged eruption cysts, especially if unilateral or painful, should prompt a thorough oral and radiographic examination for the presence of retained deciduous cheek teeth or apical infection or even jaw trauma. The practice of methodically removing “caps” at rigid set ages in horses will result in the premature removal of some deciduous cheek teeth and by removing the overlying dental sac and blood



Fig. 19. This horse has delayed eruption of a canine tooth (204) with inflamed mucosa containing a sinus tract overlying it, that may have caused recent biting problems. Following local anaesthesia, a cruciate incision was made through the overlying soft tissue and periosteum (operculum) to promote its eruption.

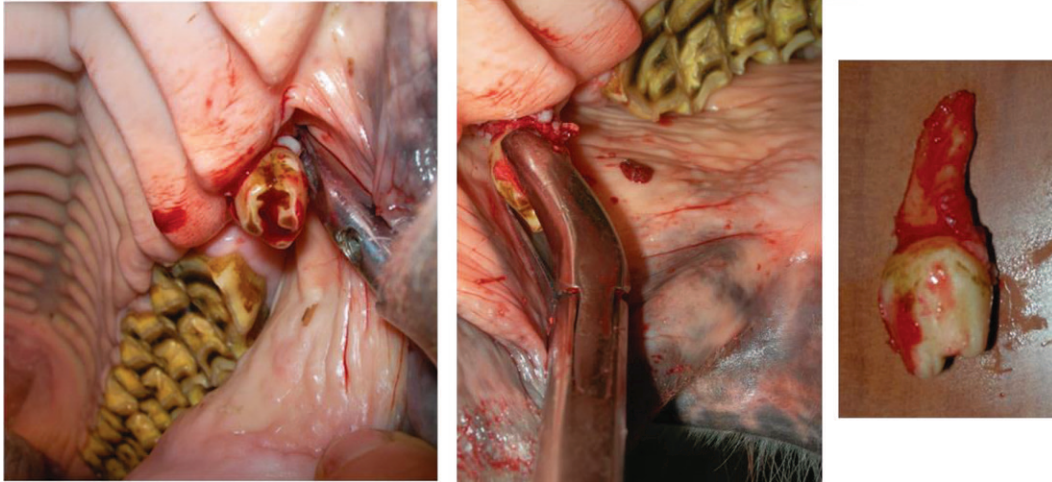


Fig. 20. There could be little debate that this very large and rostrally displaced wolf tooth (205) needed to be extracted in this riding horse. Its gingival attachments were cut and its periodontal membranes stressed using sharp, long, offset wolf tooth elevators and when loose, it was extracted intact with appropriately sized forceps, revealing its long root.

supply; this may damage the incompletely developed, underlying permanent tooth.

Diastema(ta)

Although cheek-teeth diastemata are usually a developmental disorder, the main pathological changes they cause, i.e., periodontal disease, is an acquired dental disorder. The occlusal surfaces of all six cheek teeth in each quadrant should normally be compressed tightly together (similar to incisors) with the complete row of six cheek-teeth functioning as a single masticatory unit. This, as noted, is due to the caudal angulation of the clinical crown of the first cheek tooth (06) and the rostral angulation of the clinical crowns of the last two cheek teeth (Triadan 10 and 11) compressing the occlusal aspect of all six cheek teeth together (Figs. 3 and 4). Even with normal eruption (the cheek teeth taper in slightly from clinical crown to apex) the progressively smaller reserve crowns usually remain tightly compressed at the occlusal surface until old age.

However, if diastemata develop between the cheek teeth, clinical problems inevitably occur. Cheek-teeth diastemata are often 2 to 5 mm wide, narrower at their occlusal aspect, i.e., narrow in valve diastemata or wider in open diastemata. In some cases, the cheek-teeth diastemata can be termed as *primary diastemata* that are caused by lack of angulation of the rostral and caudal cheek teeth or by cheek teeth with adequate angulation developing too far apart to provide enough compression at their occlusal surfaces (Fig. 21).^{65,71} In other cases, diastemata termed *secondary diastemata* occur adjacent to developmental or acquired displaced teeth, overcrowded supernumerary teeth, and overgrown cheek teeth at the periphery of cheek-teeth rows. In some aged horses, the eruption and thus loss of angulated reserve crown means that the narrower older teeth cannot be compressed effectively and *senile diastemata* (often multiple) occurs between them. Affected horses are often asymptomatic or

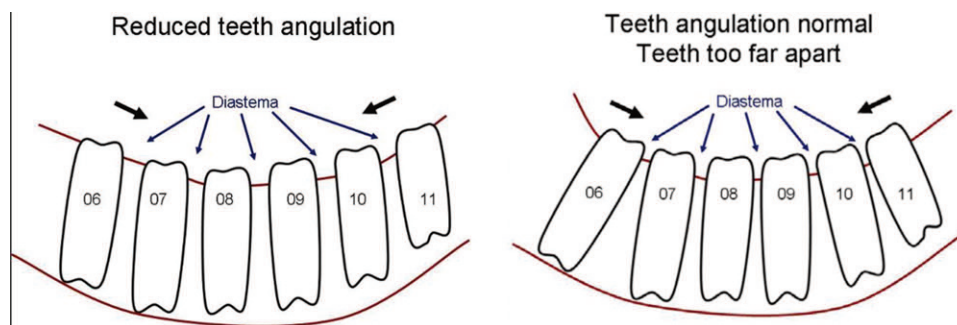


Fig. 21. These diagrams show two possible mechanisms for the development of “primary” cheek teeth diastemata in young horses. The prognosis is better for horses with normally angled cheek teeth that develop too far apart (right image), because with further eruption, these teeth may eventually develop good occlusal contact.



Fig. 22. This intraoral image shows diastemata and deep periodontal pocketing of forage between the lingual aspect of rostral left mandibular cheek teeth. More commonly, such diastemata are found between the more caudal mandibular cheek teeth, particularly between 9/10 and 10/11.

show fewer signs when at pasture compared with when indoors on forage.

Due to the prolonged mastication of horses (intermittently for up to 18 hours/day), food (usually fibrous forage) will become impacted into any abnormal interproximal (interdental) spaces. Occasionally, food will remain between the more occlusal aspects of the clinical crowns and not come in contact with the gingiva; such horses are asymptomatic and do not need treatment. More commonly, food becomes compressed more apically into the gingiva and leads to progressively deeper food impaction and gingival recession (Fig. 22). As previously described for incisors diastemata, deeper penetration of food will later cause secondary deeper periodontal disease, involving the three other periodontal tissues due to the presence of these porous foreign bodies⁷² (Fig. 23) and secondary bacterial infection including multiple species of bacteria that are also found in the healthy equine oral cavity.⁷³ Equine oral bacteriology has been a greatly neglected area until recently, partly because a high percentage of oral bacteria cannot be conventionally cultured. Thankfully, current molecular bacteriology techniques are gradually casting light on this important area.⁷³ The continued compression of food into these inflamed, sensitive tissues causes great pain during mastication. Consequently, many diastema-affected horses show severe clinical signs including quidding, biting problems, and even weight loss.^{71,74} Cheek-teeth diastema(ta) is the most common painful equine dental disease in the author's clinic.^{71,74}



Fig. 23. This oral endoscopic image of a mandibular cheek tooth diastema following removal of impacted food, shows the two adjacent teeth to be covered in a thick gray plaque, likely due to restricted intra-oral food movement. There is marked gingival inflammation with swelling adjacent to the diastema, and complete loss of gingival, and deeper periodontal tissues within the diastema.

Some horses show these clinical signs when fed forage and improve greatly when at short grass. Secondary sinusitis due to an oromaxillary fistula can also occur, especially in older horses.⁷⁵

Check teeth diastemata is the most common very painful dental disease of horses.

Cheek-teeth diastemata should be considered to be present in all horses showing quidding or other signs of painful oral disease. This disorder, which commonly affects the caudal mandibular cheek teeth, can be recognized by visually (headlight and angulated equine dental mirror or an oral endoscope essential) and by digitally detecting small spaces between the cheek teeth at gingival level, along with food fibers packed deep in the periodontal spaces between the teeth. In longer-standing cases, this food pocketing will extend along the lingual/palatal and buccal sides of affected teeth and can even extend deep into the mandible or into the maxillary sinuses.⁷⁵ Obtaining 10–15°, latero-oblique radiographs with the horse's mouth open,⁷⁶ can be very useful to investigate and especially to prognosticate on cheek-teeth diastemata cases.

Treatment of cheek-teeth diastemata can be problematic. Impacted food should always be removed from diastemata using specialized long, right-angled picks and diastema forceps and/or a high-pressure diastema pump. It can be difficult to fully debride

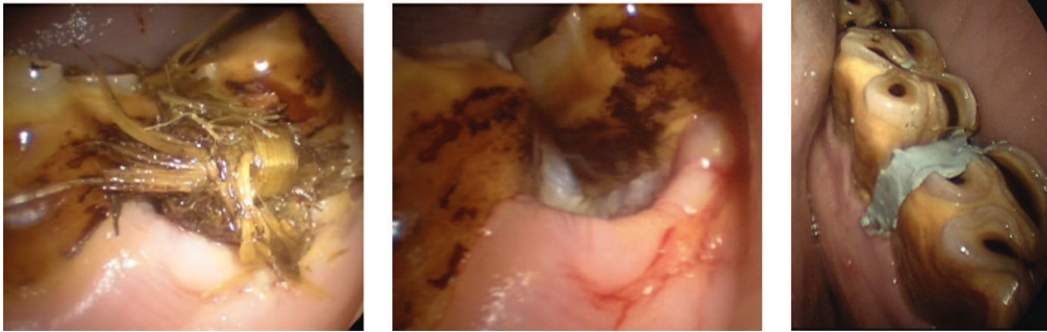


Fig. 24. The left image shows a buccal view of a valve diastema between mandibular cheek teeth packed with food and adjacent gingival remodelling and recession; the middle image shows the cleaned diastemata that has a very wide, partially epithelialized base, and more clearly shows the gingival recession. The right image is a lingual-occlusal view of this case that shows a different diastema filled with soft plastic impression material. Such valve diastemata tend to retain this packing materials for longer than open diastemata.

some forage that is deeply impacted in periodontal pockets. Removal of as much food as possible will usually give temporary clinical relief as will the administration of NSAIDs. Feeding only a finely chopped (milled) forage diet (a few mm in length), e.g., grass or alfalfa cubes often reduces or removes clinical signs as these short fibers do not become entrapped between teeth.

In younger horses with good cheek-teeth angulation and less severe diastemata, the abnormal spaces may spontaneously close with further dental eruption and drift. Consequently, widening such diastemata may just delay a natural resolution of this disorder. Cleaning and drying such diastemata and filling them with soft impression plastic material (Fig. 24) or heated wax strips, will protect the underlying periodontal pockets from filling with food, if the packing remains in place. The occlusal surfaces should be carefully examined because transverse overgrowths, i.e., tall “transverse ridges” (overgrowths on interconnected lophs) commonly develop on the teeth opposite open diastemata, which may widen the diastemata and selectively force food into them. These overgrowths should always be removed if they are detected during biannual examination of such cases.

If diastemata associated with severe periodontal disease is present, especially in older horses, widening the diastemata may result in complete cessation of quidding in many cases,^{71,74} given that food is less likely to become permanently entrapped in a wider interdental space (open diastema). Great care must be taken not to damage adjacent pulp horns during diastema widening (Fig. 25). One recent study showed complete resolution of signs in 73% (that was a long-term improvement in 51%) and partial response in 17% of cases following diastema widening. A delayed but good response was recorded for 19% of cases that took over a month to respond following diastema widening. Many cases

will need repeat treatment due to drifting of teeth into the previously widened spaces. Filling the widened diastemata with plastic materials can be of value, and may enhance the effects of widening. The use of harder acrylic filing materials can be very successful in the short term, but these fillings will eventually become dislodged due to dental movements and eruption and they may then cause severe oral trauma. Some young horses with severe, widespread diastemata will be very difficult to treat—and if radiographs show insufficient angulation of their cheek teeth, the problem will persist for life. Senile diastemata and periodontal disease can lead to tooth loss in older horses with short reserve crowns.

Rostral Positioning of the Maxillary Cheek-Teeth Row

Rostral positioning of the maxillary cheek teeth relative to their mandibular counterparts is another manifestation of the developmental craniofacial abnormality that causes incisor overjet/overbite. This abnormality eventually leads to the development of focal overgrowths on the rostral aspect of upper 06s that may cut the cheeks and interfere with the bit. If small (e.g., 1 to 5 mm high), they can be floated fully at one treatment, but when they are tall (>5 mm), reductions (odontoplasty) should be performed in stages of say 3 to 4 mm, a few months apart (Fig. 26). It may not be necessary (or possible in some cases) to fully reduce all cheek-teeth overgrowths but one must ensure that they are not causing soft-tissue trauma, restricting jaw movements, causing a diastema, or interfering with other teeth.

Similarly, overgrowths develop 1 to 3 years later on the caudal aspect of the lower 11s and frequently go undetected unless a thorough oral examination is performed. These caudal overgrowths can lacerate the adjacent oral mucosa and should be reduced with power instruments. The use of “molar cutters” and percussion guillotines (that encircle caudal

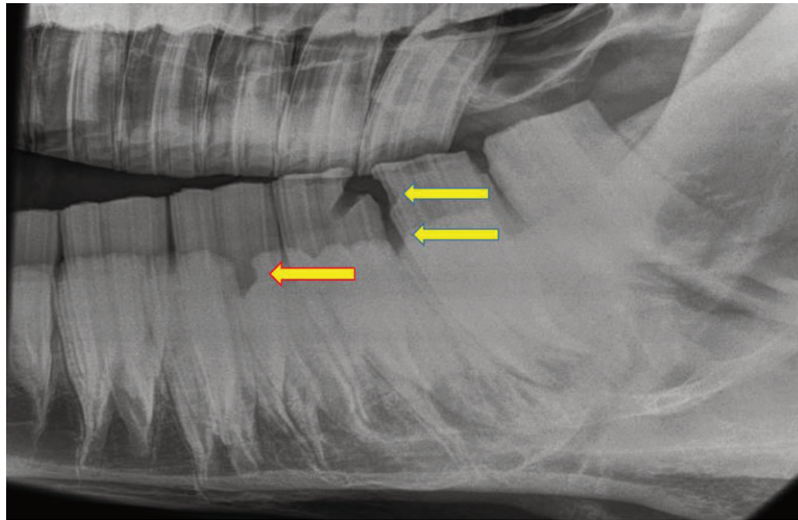


Fig. 25. Treating severe, diastema-induced periodontal disease by diastema widening is very helpful for the majority of cases. However, this procedure can be difficult between caudal mandibular cheek teeth that are always hidden by the tongue and so carries significant risks, especially for untrained operators. This radiograph is of a horse whose oral pain worsened following diastema widening. The radiograph shows gross damage to two mandibular cheek teeth (arrows). The damage to the 09 (and possibly to the 10; two arrows) will certainly have exposed at least two pulps, and is also likely that the 08 also has two exposed pulps (single arrow).

overgrowths) to remove large 311/411 overgrowths risks fracturing the teeth leading to pulpar infection and possibly oro-pharyngeal cellulitis and therefore these obsolete instruments should never be used. A marked curve of Spee (dorsal curvature of caudal mandibular cheek teeth) that is



Fig. 26. This image shows a horse with very large overgrowths of 106 and 206. Further examination of this horse also showed caudal lower 11 overgrowths and incisor overjet, all of which are dental manifestations of the same developmental craniofacial skeletal abnormality. These 106 and 206 overgrowths, parts of which are over 30 mm taller than the adjacent maxillary cheek teeth, need to be gradually reduced (possibly never to the level of adjacent teeth). This odontoplasty should be performed incrementally over a number of years in order to avoid exposing sensitive dentine or pulp.

present in some horses must not be mistaken for lower 11 overgrowths.

Cheek-Teeth Displacements

Two different causes of cheek-teeth displacements can occur in horses. The most severe medial (lingual/palatal) or lateral (buccal) displacements are developmental, possibly due to overcrowding of the dental rows during eruption or to developmentally displaced dental buds, and this type of displacement is often bilateral, and involves the lower 09s and 10s.⁶³ Rotation of the displaced tooth can also be present (Fig. 27). Large overgrowths later develop on areas of the displaced tooth and of their occlusal counterparts, which are not in normal occlusion. As noted, displaced cheek teeth usually have diastemata between them and adjacent cheek teeth that will often cause painful periodontal disease and the previously described signs. Sharp, protruding areas of displaced cheek teeth and secondary overgrowths can lacerate the oral soft tissues and cause additional oral pain. Acquired cheek-teeth displacements (usually of the caudal mandibular cheek teeth) are caused by altered orthodontic forces caused by abnormal masticatory pressure and/or directions. This type of displacement most commonly develops in older horses—possibly secondary to oral pain (such as from periodontal disease) or neglected dental overgrowths. Acquired displacements usually have lesser degrees of cheek-teeth displacement and smaller overgrowths (the latter also suggests that the displacements were recent) than developmental displacements. Smaller abnormal (lateral or medial) protrusions of teeth or overgrowths are

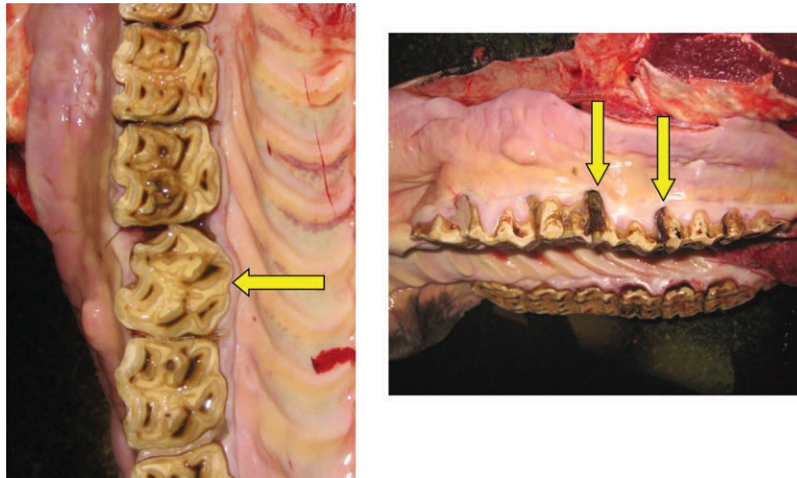


Fig. 27. These post-mortem images show a developmental partial rotation of a 208 (left image, horizontal arrow). Consequently this tooth had poor interproximal contact with the adjacent 207 and 209 and subsequent diastema formation at these sites. This has allowed periodontitis with deep food packing to develop, particularly on the buccal aspect of the diastemata between 207/208 and 208/209 (two vertical arrows).

best removed with motorized floats and any underlying reasons for acquired displacements should be addressed. Associated problematic diastemata will need to be widened and/or filled and eventually, the displaced tooth may have to be extracted, which is easier when advanced periodontal disease is present and in older horses with shorter reserve crowns.

Supernumerary Cheek Teeth

Supernumerary cheek teeth (i.e., presence of more than six cheek teeth in a row) most commonly develop at the caudal aspect of the cheek-teeth rows (especially maxillary arcades) and can be termed as *Triadan 12s* or *distomolars*.^{43,63,77} They may be unilateral, bilateral, or even multiple. Supernumerary teeth can lie in their own alveoli or alternatively can share an alveolus with an adjacent tooth. Supernumerary teeth often erupt in young adults when the normal adult teeth are erupting but can continue to develop even in teenage horses. Because of their frequent irregular shape and overcrowding, periodontal food pocketing commonly occurs between them and normal adjacent teeth (usually the Triadan 11), with resultant periodontal pain. An oromaxillary fistula can possibly develop adjacent to caudal maxillary supernumerary teeth. In addition, unopposed supernumerary teeth later develop large overgrowths (Fig. 28) that can cause soft-tissue lacerations and masticatory problems. When adjacent periodontal disease is present, supernumerary cheek teeth should be extracted (*per os* always if possible—they may have weak periodontal attachments). Other supernumerary cheek teeth without periodontitis or other supernumerary tooth-related disorders, may just require removal of their overgrowths.

Oligiodontia

Reduced number (oligiodontia) or absence (anodontia) of deciduous or permanent cheek teeth is rare in horses and may be associated with enamel and other generalized epithelial defects such as poor coat and hooves.⁷⁸ Absence of teeth allows drifting of adjacent teeth, with possible development of secondary periodontal disease or overgrowths of the opposite teeth. Loss of teeth in



Fig. 28. Intra-oral image of a right maxillary cheek teeth row of an adult horse showing a supernumerary cheek tooth lying palatally to 208 and 209. This tooth has not caused any soft tissue damage but has slightly displaced and caused periodontal disease (to apical level) between 208 and 209 and also between these two teeth and the supernumerary tooth. Consequently, all three teeth had to be (orally) extracted.



Fig. 29. This figure shows three different examples of cheek teeth dysplasia. On the left is an abnormally large tooth that has abnormal distributions of dentine, cementum, and enamel, including excessive cementum but virtually no enamel. Consequently this tooth has little wear resistance and has been hollowed out and there is an overgrowth on the opposite 406. The central image shows an enlarged, dysplastic tooth with additional enamel with additional infundibular-like structures. This dysplastic tooth caused excessive wear on the opposing normal tooth, in contrast with the usual situation where the dysplastic tooth is softer than normal. Right: this mandibular tooth has infundibular-like structure between pulp horns 3 and 4, that developed deep caries and thus caused apical infection to develop in this tooth.

older horses due to wear or intercurrent disease (usually periodontitis) is not oligiodontia.

Dysplasia

Abnormal development can occur in any or all of the cheek-teeth tissue components. Some examples of different types of cheek-teeth dysplasia are presented in Fig. 29.

3. Acquired Disorders of Cheek Teeth

Occlusal Wear Abnormalities and Overgrowths

Some cases of uneven occlusal wear, including slight degrees of *wavemouth* are caused by delayed eruption of the permanent cheek teeth in either the maxillary or mandibular rows, with overgrowth of the opposite teeth, that may then remain for life. Other, (more focal) overgrowths develop on a normal tooth that lie opposite a missing tooth or a tooth with low enamel content that has low wear resistance. Such untreated localized overgrowths may initiate further abnormalities of wear such as *wavemouth* and more rectangular overgrowths termed *step-mouth*. Recognizing and removing or reducing such developmental overgrowths at an early stage is the key to their successful treatment.

The overgrown tooth is usually the normal tooth. Examine the opposing tooth for abnormalities.

Because of their prolonged eruption (for circa 20 to 25 years in large horse breeds and up to 40 years in donkeys and small ponies) any areas of equine teeth that are not in full occlusion with an opposing tooth containing similar levels of enamel will eventually

develop overgrowths on the unopposed areas. Domestication has greatly altered the equine diet with many horses being fed large quantities of very caloric concentrates and consequently eating much less forage over a shorter period. Feeding concentrates also greatly alters the masticatory action of horses, causing them to chew with a more vertical than lateral mandibular action.⁷⁹ This restriction of full lateral mandibular movements predisposes horses to develop cheek-teeth overgrowths, initially composed of enamel, but larger overgrowths also contain dentine and cementum, despite being often termed “enamel points.” These overgrowths are exacerbated in horses whose maxillary cheek teeth have prominent vertical ridges (cingulae; Fig. 30) and some horses with this anatomical dental variation develop sharp buccal edges on these cingulae that will cause buccal ulceration, even when fed a 100% forage diet.

The previously described absence of complete occlusal contact between the equine upper and lower cheek teeth (anisognathia) and angulation of their occlusal surfaces are further predisposition to the development of dental overgrowths that develop buccally (laterally) on the maxillary, and lingually (medially) on the mandibular cheek teeth. If these dental overgrowths are neglected, the sharp “points” may eventually merge into a steeply angulated (e.g., >45°) occlusal surface termed *shearmouth* (*scissor mouth*), although there may be additional craniofacial anatomical predispositions to shearmouth. A mechanical obstruction will now additionally obstruct or even prevent the normal side-to-side mandibular movements, and mastication will be even less effective.

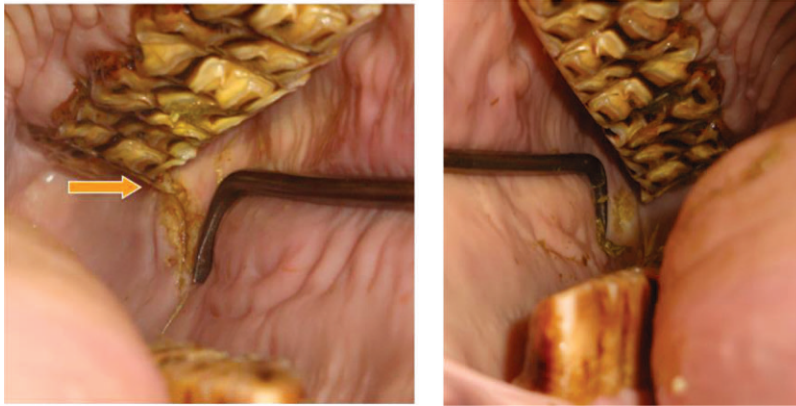


Fig. 30. These images reinforce the role of cingulae (vertical ridges on the buccal aspect of maxillary cheek teeth) in causing dental-related buccal ulceration. This horse had its teeth “routinely floated” some days previously, during which the operator, rather excessively, bilaterally removed all of the occlusal aspect of these cingulae, except the caudal one on each side (arrow). These two residual cingulae are now taking all of the cheek pressure and thus have caused ulceration of the overlying buccal mucosa. This horse, which was asymptomatic prior to dental floating, now has oral pain and biting problems!

A major role in equine dental care is to prevent large dental overgrowths from developing by their early detection during routine oral examinations and their effective removal.

In advanced cases of dental overgrowths, affected animals may not be able to fully clear their mouth of food. Consequently, semi-permanent, “hamster-like” cheek swellings may occur due to the accumulation of fibrous food between the lateral aspects of the cheek teeth and the cheeks, with secondary periodontal disease. In the presence of oral pain, some horses may also chew very slowly, make soft slurping sounds when masticating forage (rather than the normal vigorous crunching sounds). Some affected horses may permanently use one side of their mouth for chewing rather than using alternative sides, or they may hold their head in an abnormal position when masticating. Affected horses may readily eat grass or mashes but are reluctant to eat forage. Decreased food intake and inefficient food digestion and utilization may eventually occur, sometimes leading to weight loss. Long strands of forage and undigested whole cereal grains may be visible in the feces of such cases. Paradoxically, some horses with large amounts of undigested long forage in their feces will have very loose feces or diarrhea.

Painful dental-related lesions may also cause bit (bitting) problems, including abnormal head carriage and headshaking during work because the “enamel” overgrowths on the upper cheek teeth cut the inside of the cheeks due to bit and noseband pressure. Less commonly, overgrowths on the lower cheek teeth may be forced against the tongue by the bit and also cause lacerations.

As unopposed cheek teeth erupt abnormally fast and also have less occlusal stimulus to lay down subocclusal secondary dentine, there is a great likelihood that if a large cheek tooth overgrowth (e.g., a

20-mm long *stepmouth*) is fully reduced (floated) to the level of the remaining cheek teeth, some pulps will be exposed. This is because insufficient secondary dentine has developed to occlude the pulp cavity to the level of the occlusal surfaces of adjacent teeth.⁸⁰ Treatment of these abnormalities should be a staged removal of major overgrowths using manual or motorized equipment over many months or even years, and some do not need to be fully reduced.

As noted, when there are unequal amounts of enamel in opposing teeth due to acquired disease such as infundibular caries of upper teeth, dental displacement, senile loss of dental enamel (*smooth mouth*), or even complete loss of teeth, the opposing teeth will overgrow. Following tooth loss, the opposing tooth will erupt more rapidly, leading initially to rectangular overgrowths termed *stepmouth* that later may become triangular in shape due to dental drift into the extraction space. Treatment of horses with *shearmouth*, *wavemouth*, and *stepmouth* is often palliative (20 years of dental neglect cannot be reversed!) and consists of extraction of digitally loose teeth, removal of overgrowths that are causing soft-tissue trauma or restricting normal masticatory movements, treating diastemata/periodontitis, and possibly reducing slightly loose teeth by a few millimeters in the hope they can now reattach more firmly (Fig. 31). Such cases should have an increasing portion of their dietary forage “pre-masticated,” i.e., mechanically ground down (i.e., “senior diets”).

Very loose teeth can be extracted orally using cheek-teeth extractors in standing sedated horses. However, all loose teeth do not have to be extracted, especially in older horses, because as noted, they may reattach when overgrowths are reduced. The aim should be to prevent the development of such end-stage disorders by regular (annual or biannual)

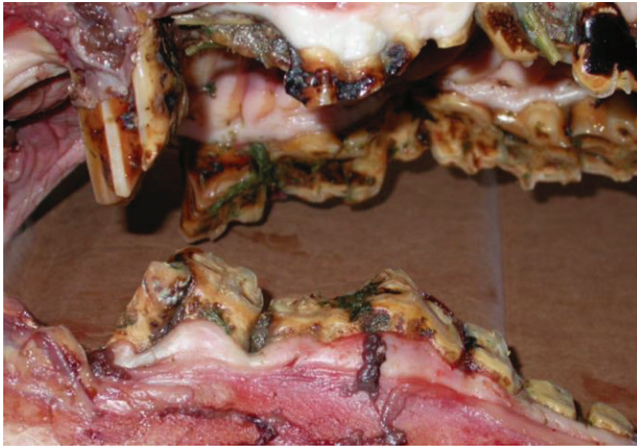


Fig. 31. This post-mortem image shows an example of long-term gross dental neglect. The dental disorders in this specimen include loss of teeth, many large overgrowths (including so called stepmouth), wavemouth, shearmouth (second arcade), diastemata, peripheral caries, and periodontal disease. A major role of the equine veterinarian is to prevent such irreversible, long-term changes from developing.

dental inspections and appropriate treatments including removal of any detected overgrowths, thereby encouraging normal masticatory activity and allowing the free movement of food and saliva around the oral cavity.

Older teeth may develop a (concave—cupped out) occlusal surface termed “*senile excavation*.” Such abnormal wear is caused by absence of the enamel folds due to the wearing out of the infundibular enamel (in upper cheek teeth) and of the peripheral enamel infolding (mainly in the lower cheek teeth) that normally prevents such excessive wear of the adjacent dentine. Such horses with senile dentition may develop sharp dental overgrowths on the caudal aspect of the upper 11s and the palatal aspect of the maxillary cheek teeth. *Smooth mouth*, i.e., absence of enamel on the occlusal surface of cheek teeth, is common in older horses; however, many others lose their cheek teeth from secondary periodontal disease prior to this stage. Later, the individual roots will become exposed and may display the characteristic hypercementosis of aged equine teeth.⁸¹

Primary Periodontal Disease

Unlike species with brachydont teeth, primary periodontal disease is not a significant problem in the horse.¹⁴ During eruption of the permanent dentition, a transient inflammation of the periodontal membrane occurs in many horses. Due to the prolonged eruption and continuous development of new periodontal fibers in the horse, equine periodontal disease is not necessarily irreversible, as is often the case with brachydont dentition. Many horses will have limited periodontal disease (gingivitis) around their canine teeth due to calculus, but rarely will

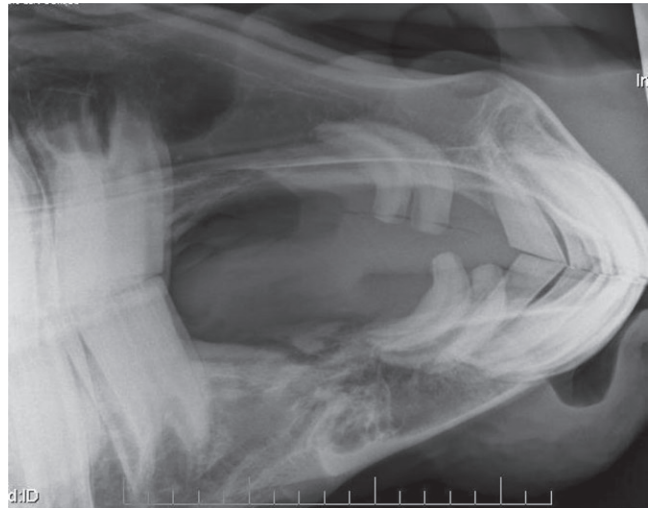


Fig. 32. Lateral head radiograph of an adult male horse showing osteitis and sequestrum formation of the dorsal aspect of the mandibles (mandibular bars of the mouth—physiological diastema). This severe mandibular damage was caused by the horse standing on its reins traumatizing its mandible with the bit. Gross misuse of the bit can cause similar mandibular trauma (“polo pony mouth”) resulting in osteitis and sequestration, usually more caudally on the mandible.

this progress to deep periodontal disease. Clinically significant periodontal disease in the horse is invariably secondary to diastema or malocclusions as described earlier and is managed as previously described.

4. Traumatic Disorders of Oral Cavity

In addition to the more common swellings caused by the developing permanent cheek teeth (eruption cysts, “3- and 4-year-old bumps”) or apical infections, swellings of the maxillary and more so of the mandibles can also be caused by external trauma (usually due to kicks), biting injuries (Fig. 32), and less commonly, by tumors. In the young horse traumatic mandibular fractures will inevitably cause some damage to the cheek teeth reserve crowns, which occupy much of this bone, but these long reserve crowns usually stabilize the mandibular fracture. In most cases conservative therapy (e.g., 2 weeks of antibiotic therapy and feeding a soft diet such as soaked senior diet for 6 to 8 weeks) is adequate, with the long cheek teeth and undamaged contralateral mandible acting as effective splints. Even if external sinus tracts do develop, it is worthwhile persevering with conservative therapy, until radiographic changes (using a metallic probe in any sinus tract) confirm the presence of definitive dental infection. In any case, extraction should be delayed for some months to minimize the chance that the extraction procedure causes displacement of the mandibular fracture. Iatrogenic trauma to teeth and caudal mandible can also be (less common now-

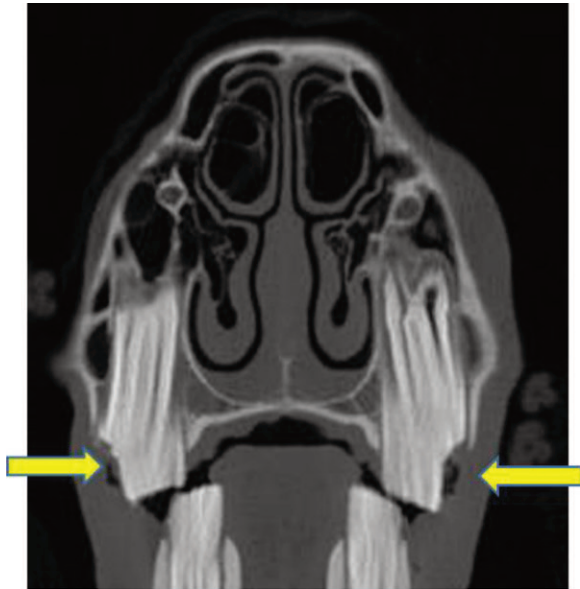


Fig. 33. This transverse computed tomographic image through the 109 and 209 of a horse with idiopathic slab fractures (fractures through pulp horns 1 and 2) present in both of these teeth. The 109 fracture (left in image) is asymptomatic and the overlying pulp horn and apex show no detectable imaging abnormalities. The 209 (right) has gas (indicative of gas producing bacterial infection) in a buccal pulp horn, widened periapical periodontal space, overlying sinus mucosal thickening, and soft-tissue swelling over the adjacent maxillary bone, indicating that the pulpar exposure was not sealed off by tertiary dentine in this tooth, with subsequent infection of these pulps that spread to the periapical area.

adays) caused by the use of dental shears to reduce tall dental overgrowths.

Bit-induced injuries to the mandibular interdental space (bars of mouth) and of lips and gingiva can be caused by excessive bit pressure. A superficial periostitis or sequestration of the mandibular cortex may occur following bit trauma (“polo pony mouth”) but widespread bone infection and pathological fractures of the mandible can also occur. Physiological bony exostoses can sometimes be present at the insertion of the buccinator muscles and these are sometimes diagnosed as “bone spurs” and needlessly surgically removed.

5. Idiopathic Fractures of Cheek Teeth

Cheek-teeth fractures that are present in the absence of any known trauma have been termed *idiopathic cheek teeth fractures*¹⁴ and are commonly found in horses, usually affecting the upper cheek teeth.^{16,82,83} These fractures can run through the pulp horns in a variety of patterns. The most common pattern has been termed a *slab fracture* that occurs through the two buccal (lateral) pulp horns (pulp horns number 1 and 2) (Fig. 33) at alveolar crest level, with the upper 09s the most commonly affected Triadan position. Mandibular cheek teeth less commonly suffer from such lateral sagittal frac-

tures through pulp horns 1 and 2. However, in the lower cheek teeth (that have no infundibulae), these fractures are close to the sagittal midline of the tooth. Maxillary cheek tooth slab fracture sites usually become filled with food, thus displacing the smaller lateral cheek-tooth fragment buccally into the cheeks, causing buccal lacerations in addition to stretching periodontal ligaments, subsequently causing quidding and biting problems. Spontaneous loss (usually within a few days) or extraction of the smaller, loose fragment (using cheek-teeth-fragment forceps) usually resolves the clinical signs. However, pulpar exposure always occurs in these cases and evidence of apical inflammation and alveolar remodeling on imaging is often present in these fractured teeth. In maxillary (but seldom in mandibular) cheek teeth, the two exposed pulp horns commonly become effectively sealed off from the fracture site by tertiary (reparative) dentine, and the remainder of the endodontic system and fractured tooth remain vital and the tooth continues to erupt normally. In contrast, apical infection and death of the fractured tooth occurs commonly with mandibular cheek teeth pulp horn 1 and 2 fractures and consequently, occlusal pulpar exposure can later be recognized in the remaining larger lingual (medial) fragment. With the death of any remaining dental fragment, it will likely have to be removed within a year or so when it loosens, further fractures, or causes clinical signs of apical infection, such as sinusitis or maxillary or mandibular swelling.

Midline (sagittal) fractures of the maxillary cheek teeth occur less commonly than slab fractures, and the 09s are again most commonly affected. This type of fracture is now known to be secondary to advanced infundibular caries as described below, with coalescence of two carious infundibula leading to mechanical weakening of the tooth (Fig. 34), followed by fracture formation (Fig. 35). As the etiology of these fractures is known, they should no longer be classified as “idiopathic fractures” and the term *infundibular caries-related cheek teeth fracture* has been proposed.⁸⁴

Maxillary Cheek Tooth Infundibular Caries

Caries is characterized by decalcification and destruction of the calcified dental tissue and destruction of its organic dental components. Infundibular caries is believed to be caused by acidogenic bacteria present in food that becomes impacted in infundibulae that have defects in their cementum (Fig. 36), thus allowing cariogenic bacteria to proliferate at this site. The above-noted maxillary cheek tooth infundibular caries has been recognized for more than a century, including by Colyer³⁵ (1906) and later by Honma et al⁴⁵ (1962) who described an equine caries grading system, later modified by Dacre,⁸⁵ which is currently the standard grading system used to classify the severity of both infundibular and peripheral caries (Fig. 37).

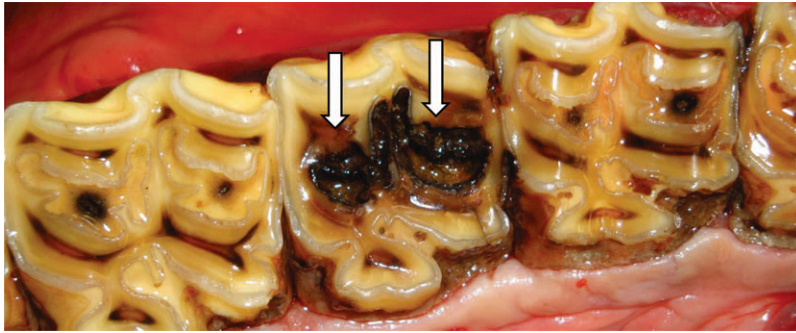


Fig. 34. This maxillary cheek tooth has marked caries of both rostral and caudal infundibulae (arrows), that have almost coalesced. The dark discoloration of the infundibular enamel suggests that the enamel is carious (i.e., grade 2 infundibular caries) and the brown staining of the adjacent dentine shows that it is also carious (i.e., grade 3 infundibular caries). This tooth is now mechanically weak midline and may fracture. Alternatively, the infundibular caries may penetrate to the pulp horn and cause apical infection. This tooth is an ideal candidate for infundibular restoration.

This caries causes destruction of the remaining (often porous) cementum and can possibly extend to the underlying enamel, or even dentine and pulp. Infundibular cemental defects are common with recent studies showing approximately 90% of all infundibulae (especially in the Triadan 09 position) to be incompletely filled with normal-appearing cementum and this defective cement likely predisposes to the development of caries.^{6,18,27,86,87} Marked infundibular cemental caries was found in 8% of infundibulae, with the Triadan 09 positions disproportionately accounting for 47% of these carious infundibulae.⁶

Infection of the underlying pulp and periapical aspect of the tooth commonly ensues with infundibular caries-related fractures and can extend to

cause a secondary maxillary sinusitis (*dental sinusitis*) (Fig. 38). In the presence of clinical signs of apical infection, all parts of the fractured tooth must be extracted, *per os* if possible, even though the clinical crown is weakened. This can best be performed by cleaning out the food in the fracture site and using cheek-tooth extractors to close the two fragments together if possible, followed by gently rocking the combined fragments until the tooth is loose. If much concurrent periodontal disease is present, extraction is usually easy. If the weakened teeth further fracture during this procedure, it may be possible to extract the residual fragments using a variety of long-handled, specialist equine dental picks. If this technique is unsuccessful, a

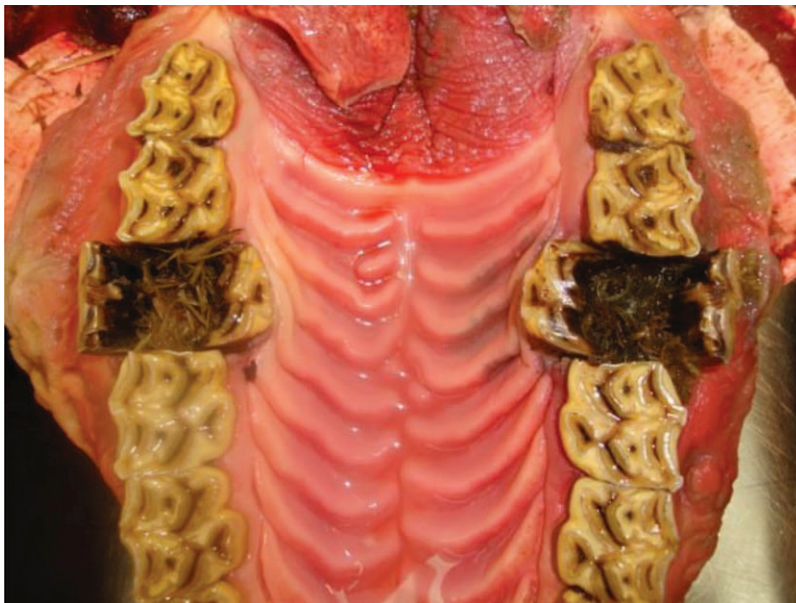


Fig. 35. This post-mortem image shows infundibular caries-related, midline sagittal fractures of both upper 09s, with palatal and buccal displacements of the fragments. Such cases have severe oral pain with masticatory and biting problems and many also develop dental sinusitis due to apical infection of these fractured teeth. (Image courtesy of Istvan Gere)



Fig. 36. This longitudinal section of a young maxillary cheek tooth shows one of its two infundibulae sectioned over its full depth. There is an area of complete cemental aplasia toward the infundibular apex (red arrow) with some dark stained, porous, hypoplastic cementum more occlusally to this. More centrally, the infundibulum is completely filled with normal-appearing cementum (blue arrow). Occlusally, there is a small carious infundibular cemental defect open to the oral cavity (yellow arrow). These hypoplastic cemental defects and localized occlusal caries lesions are commonly asymptotically present in equine maxillary cheek teeth.

minimally invasive transbuccal technique can be used, as described later.

Cemental hypoplasia of the infundibulae of the rostral three cheek teeth could be caused by early destruction of the dental sac, such as by premature removal of overlying deciduous “caps.” However, a recent study of cheek teeth 1 to 3 years following their eruption (*dental age*) showed a viable blood supply to the apex of infundibulae in many teeth. This alternative blood supply allows continued infundibular cemental deposition to occur for some years following eruption—but infundibular cementum deposition is often incomplete, especially in the 09s.^{6,15} *Streptococcus devriesei* is a recently described bacteria isolated from equine cheek teeth infundibular caries (IC) lesions but its precise role in the aetiopathogenesis of IC remains unclear. It has been proposed that feeding high levels of concentrates to horses provides a source of fermentable

carbohydrates that predisposes to infundibular caries, in contrast with brachydont dental caries, where simple sugars have been shown to be a substrate for cariogenic bacteria to produce the acids that cause caries.⁸⁸

6. Peripheral Caries

Peripheral caries, an increasingly recognized or possibly more prevalent disorder, can affect all of the dental calcified tissues (cementum, enamel, and dentine), and so the term *peripheral caries* is preferable to the previously used term of *peripheral cemental caries*.^{20,89} Examples of different grades of peripheral caries are shown in Fig. 39. The mechanism of development of equine peripheral caries is believed to be similar to the development of caries in brachydont species and has recently been reviewed.⁸⁸ Essentially, the normal organic biofilm (pellicle) covering all equine teeth becomes thicker, i.e., forms a plaque with concurrent changes in the complex bacterial flora within this biofilm, including a tendency for cariogenic bacteria to proliferate and ferment simple carbohydrates to produce acids that demineralize the underlying cementum. In more severe cases, the underlying enamel or even dentine are affected, predisposing these teeth to premature wear or fracture. By removing interproximal cementum, peripheral caries creates spaces between the teeth and thus may predispose to diastema and secondary periodontal disease but the etiological relationship between cheek teeth peripheral caries and diastemata remains contentious.

Peripheral caries most commonly affects the caudal three cheek teeth (Triadan 09–11). It has been suggested that because the main equine (parotid and mandibular) salivary ducts drain rostrally in the mouth, that the buffering effect of saliva on oral pH may be less in the caudal aspect of the equine oral cavity (Gere and Dixon⁹⁰).

The prevalence of equine peripheral caries seems to be increasing in Europe, usually grade 1, i.e., affecting peripheral cementum only. Wafa⁴⁸ recorded a peripheral caries prevalence of 0.3% in a post-mortem study in Ireland; a 0.9% prevalence was found in a 1990 dental survey in Swedish horses;⁹¹ but a Swedish post-mortem study 20 years later reported a prevalence of 6.1%.⁹⁰ A clinical survey of donkeys in Spain and Portugal showed a similar prevalence of 5.9%.⁹² In contrast, a very recent United Kingdom-wide clinical survey has shown a much higher prevalence (52%) than all previous studies.⁹³ It is unclear whether this high prevalence is partly due to increased recognition of this disorder or is due to a true increase in prevalence. The Swedish study suggested that the feeding of haylage and higher levels of concentrates predisposed to peripheral caries;⁹⁰ however, a large epidemiological survey did not show any clearcut relationship between diet and the prevalence of peripheral caries.⁹³

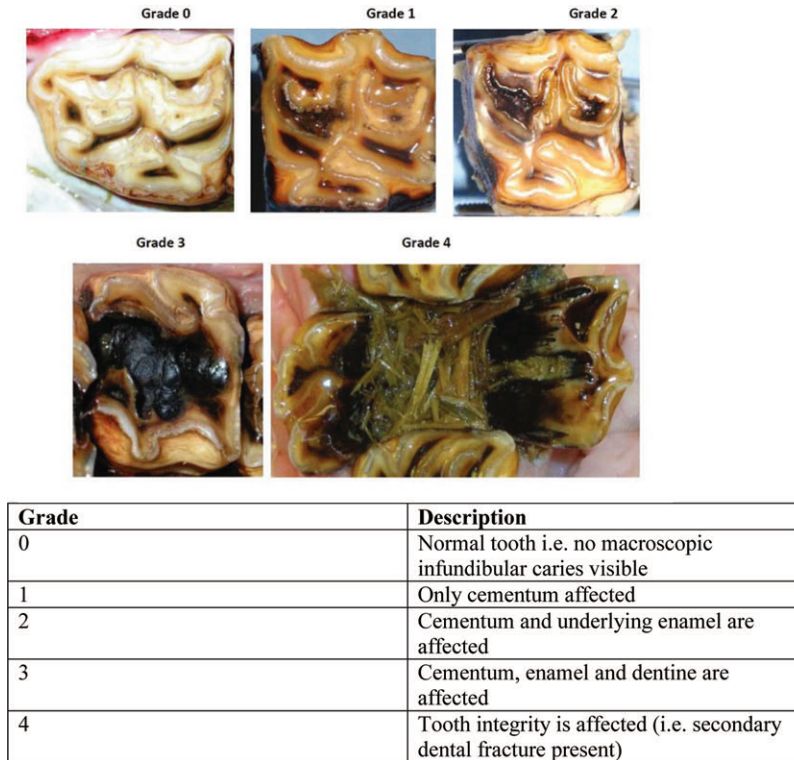


Fig. 37. Grading system for equine infundibular caries. Image courtesy of the editor of *Equine Veterinary Education*.

Severe peripheral dental caries involving all classes of teeth (incisors, canine, and cheek teeth) have been found in some groups of horses fed high-concentrate, low-roughage diets, where the reduced time spent masticating high levels of more fermentable, simple carbohydrates may predispose to prolonged periods of low oral-cavity pH that causes

demineralization of calcified dental tissue. Individual horses may be susceptible to this disorder. Peripheral caries is also concurrently found with other dental abnormalities where restricted food and saliva movement may predispose to its development. Extensive generalized damage to teeth *not* induced by acids produced by oral bacteria i.e., *den-*

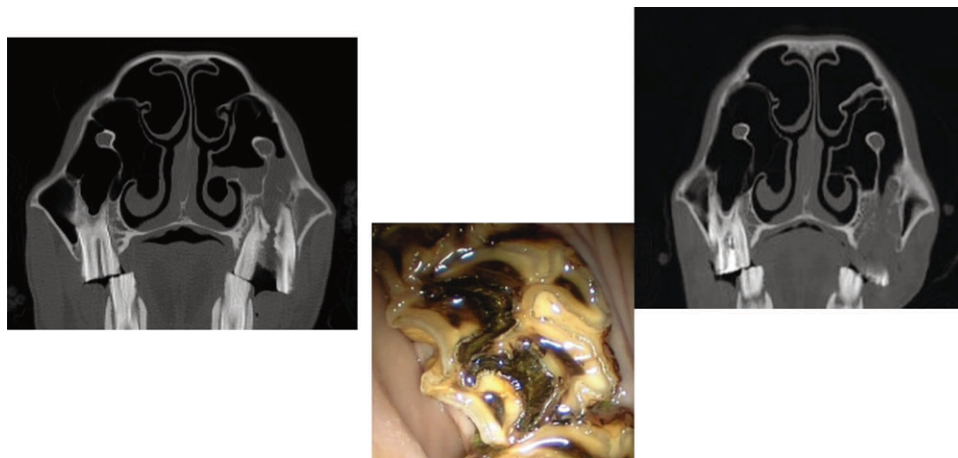
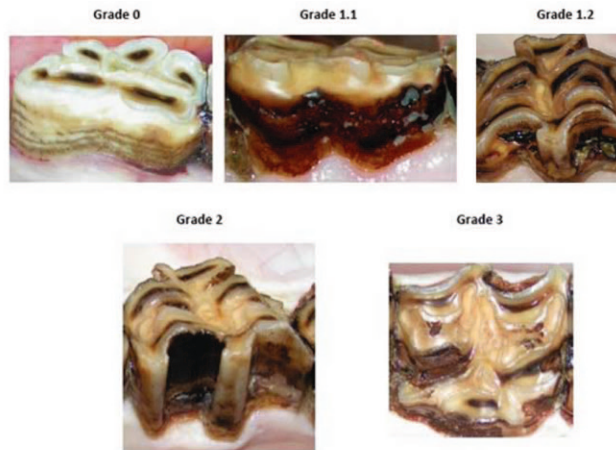


Fig. 38. The computed tomographic image on the left shows an infundibular caries-related, midline sagittal fracture of maxillary cheek tooth (209), with destruction of the overlying alveolus and secondary empyema of the rostral maxillary and ventral conchal sinuses. The middle image is an oral endoscopic image of the occlusal aspect of the contralateral tooth (109) that has marked (grade 3) infundibular caries of its rostral infundibulum and grade 2 caries of its caudal infundibulum. The right image shows a further computed tomographic image of this case following extraction of the fractured 209 and infundibular restoration of the 109. It is not uncommon for air bubbles to be present in such infundibular restorations due to the effect of gravity on flowable restorative materials.



Grade	Description
0	Normal tooth i.e. no macroscopic peripheral caries visible
1.1	Only cementum affected: lesions appear as superficial erosions or pitting lesions or even as extensive erosions of the cementum (cement) surface, although there is still some underlying cementum left.
1.2	Only cementum affected: more severe peripheral caries where the cementum is completely lost in some areas of the tooth, exposing the underlying (but unaffected) enamel.
2	Cementum and underlying enamel are affected
3	Cementum, enamel and dentine are affected

Fig. 39. Grading system for equine peripheral caries. Image courtesy of the editor of *Equine Veterinary Education*.

tal erosions that are similar to caries have also been recorded in horses where excessive acids were added to silage (haylage).²⁰

7. Cheek Teeth Periapical (Apical) Infections

Bacterial infections of the periodontal tissues of the cheek-teeth apices (true roots may not be formed at this time) are a very significant problem because they commonly cause osteomyelitis of the supporting bones or sinusitis. This is because the apical infections commonly occur in younger horses that have long reserve crowns and thus the infection cannot drain into the oral cavity, as occurs in older horses with shorter reserve crowns. Consequently, the infection spreads to the adjacent bony structures. Mandibular apical infections in younger horses are inevitably accompanied by unilateral, painful mandibular swellings, often with external draining tracts. Infections of the upper 06s and 07s (occasionally the 08s) will cause focal swellings of the rostral maxilla, which are almost pathognomonic for dental infections (Fig. 40). An external sinus tract will develop in some cases; less commonly, exudate will drain into the nasal cavity causing a chronic, uni-

lateral, purulent infection. Infections of the caudal three to four maxillary cheek teeth generally results in a secondary sinusitis, with the presence of a chronic, malodorous, unilateral nasal discharge.⁵⁷

In older horses, apical infections may just drain through the periodontal membrane or occlusally open pulp horns into the mouth, and therefore clinical signs of infection of the supporting jaws will usually not occur. Apical infections that arise as an extension of deep periodontal disease from abnormal spaces surrounding the cheek teeth including supernumerary teeth, diastemata, developmental, and acquired dental displacements will obviously drain into the mouth via this periodontal route. Less frequent signs with cheek teeth apical infections are quidding, halitosis, and epiphora if the nasolacrimal duct becomes obstructed.

If an apical infection (with death of some or all pulp horns) has been present for very many months, the secondary dentine that is worn away on the occlusal surface by normal attrition cannot be replaced. Dental eruption continues in apically infected teeth due to normal periodontal remodelling even if the tooth is endodontically dead and so oc-

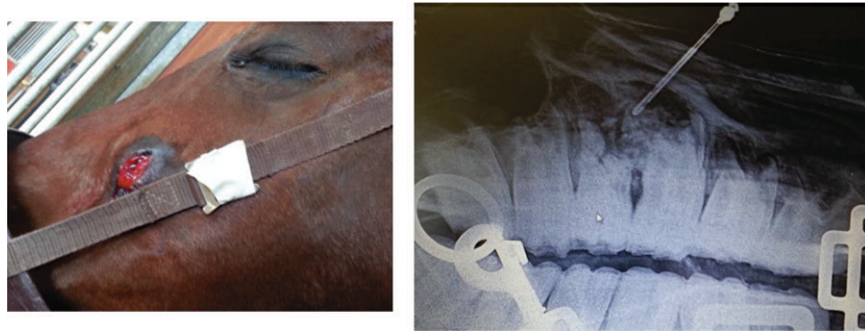


Fig. 40. This image shows a horse with a chronic sinus tract just dorsal to the rostral aspect of its left facial crest (a pathognomonic site for dental related swellings/tracts). The radiograph of this case was taken with a metal cannula inserted into this tract. This probe leads to an area between the 208 and 209, both which have gross destruction of their apices and some reactive cementum deposition. It is not clear whether a very destructive infection of one apex damaged its alveolus and led to an apical infection of an adjacent tooth.

clusal pulpar exposure can eventually occur over affected pulp horns (Fig. 39).^{25,94,95} Examination for pulpar exposure using a dental mirror or endoscope and a fine steel probe is a simple and currently underused, valuable clinical test for establishing dental viability.

Infection of the cheek-teeth apices can occur through a variety of routes, including deep periodontal disease, midline sagittal or other dental fractures, infundibular caries, some fissure fractures, or dental dysplasia.^{20,87,95} However, apical infections of cheek teeth is most commonly caused by blood- or lymphatic-borne infections (anachoresis) and inflammation of the pulp due to dental impaction may predispose to such infections. Periapical abscessation of the lower cheek teeth (possibly bilateral) believed to be caused by anachoresis commonly occurs within 1 to 2 years of eruption and may occur with or following the development of eruption cysts (“3- and 4-year-old bumps”) (Fig. 41).

Cheek-teeth occlusal hairline or fissure fractures (usually transversely oriented), are a potential cause of apical infections, particularly if darkly stained and close to a pulp horn. If these criteria are not met, they are usually believed to be etiologically insignificant and two large oral endoscopic studies have not found any direct association between this type of fracture and apical infection.^{96,97}

Another possible cause of apical infection of the upper cheek teeth only, are food accumulation and fermentation deep in infundibular cemental defects (infundibular caries) leading to caries of enamel and dentine and then spread of infection to the adjacent pulp horns.^{25,87} As noted, infundibular caries can also cause coalescence of both infundibulae, and lead to a midline sagittal fracture with apical infection commonly occurring in these fractured teeth.¹⁴

Diagnosis of Cheek Teeth Apical Infection

A thorough clinical (including intra-oral examination with a mouth gag, including for the presence of fractures or pulpar exposure) and radiographic evaluation of the dental apices (latero-oblique projections) should always be undertaken first to absolutely confirm that a tooth needs to be extracted and then to confirm *which* tooth is diseased (Figs. 40, 42, and 43). The interpretation of equine dental radiographs can be difficult and consequently they are often inaccurate in the diagnosis of early cheek-teeth apical infection. In such cases, advanced imaging, especially computed tomography, can provide conclusive evidence of apical infection (Fig. 44). If an external sinus track is present, e.g., as occurs with many mandibular or rostral (first to third) maxillary cheek-teeth infections, it is essential to obtain radiographs with a metallic probe *in situ*, to

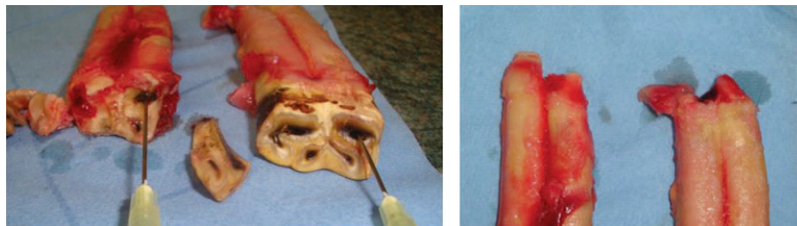


Fig. 41. These two mandibular 08 cheek teeth were extracted from a 5-year-old pony with bilateral mandibular swellings. Both teeth have pulpar exposure (see needles in occlusal aspect of pulp horns) and small apical granulomas (right image). In the absence of any clinical crown fracture or periodontal lesions of these teeth, the etiology of these apical infections was considered to be a vertical impaction of these teeth with secondary anachoretic infection of the pulps and large eruption cysts.

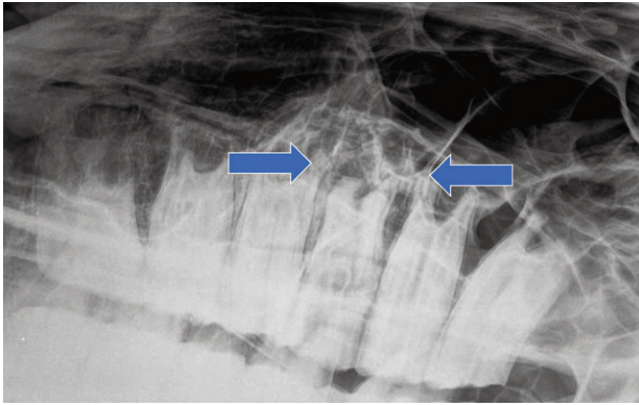


Fig. 42. Radiographs are often unreliable in detecting early cheek teeth apical infections. However, some chronic cases of apical infection do have conclusive radiographic evidence of such disease, including this case that has blunting of the roots of an apically infected tooth, and a lucent periapical area surrounded by a diffuse, radiopaque alveolar area. Note that the crown of this tooth looks more radiolucent than adjacent teeth. However, such radiolucency can be a feature of clinically normal maxillary 09s because they often have infundibular cemental defects and possibly later, infundibular caries.

define the infected area of the tooth (Fig. 40). This procedure will also provide surgical landmarks, if a loose infected tooth is to be extracted by Steinman-pin repulsion. Similarly, metallic markers (e.g., skin staples) should be placed over areas of maximal facial swelling to establish possible anatomical rela-

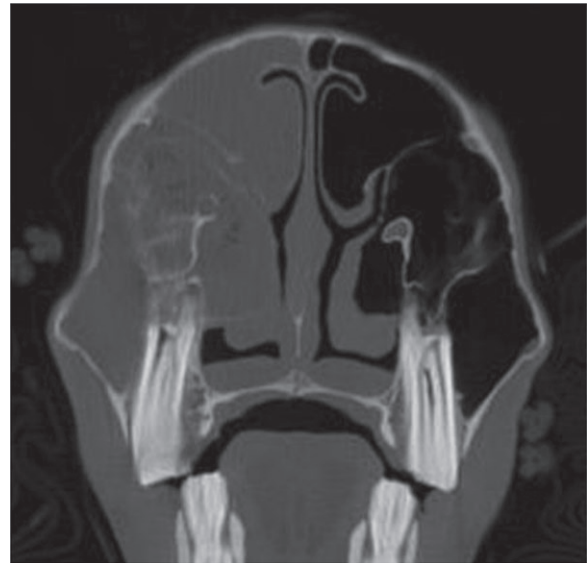


Fig. 44. This computed tomographic image shows a horse with right-sided dental sinusitis. There is apical infection of the underlying maxillary cheek tooth as manifested by a large amount of gas in its buccal pulp horn, lysis, and fragmentation of a buccal root and destruction of the overlying alveolus. This apical infection has led to the ventral conchal, maxillary, and dorsal conchal sinuses all becoming infected and they are now filled with pus, some which is inspissated, as indicated by the presence of gas (black dots) in some of the exudate.

tionships between facial swellings and the underlying cheek-teeth apices.

In suspect maxillary cheek-teeth apical infections, endoscopic examination of the nasal cavity should



Fig. 43. This radiograph shows the apical region of a maxillary cheek tooth with advanced apical infection, as evidenced by destruction of the normal apical and alveolar architecture and much reactive cementum deposition. On the right, the extracted tooth shows gross reactive hypercementosis of its infected apex—a feature that can make exodontia very difficult.

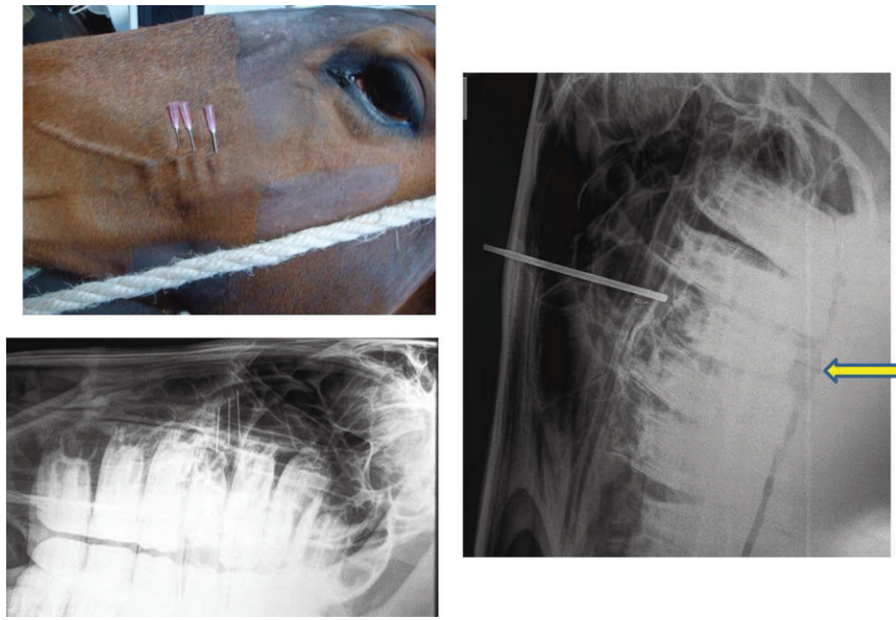


Fig. 45. Steinmann pin repulsion of a carious maxillary cheek tooth whose clinical crown fractured during extraction. The top image on the left shows the affected horses with a row of 18-gauge hypodermic needles inserted subcutaneously level with the estimated site of the fractured tooth. The radiographs (bottom left image) shows that these needles are a little too caudal in position and are also directed too caudally. The radiograph on the right, taken during the Steinman pin repulsion of the tooth, shows the pin to be properly positioned and appropriately angled. Note the loss of the clinical crown of this tooth (arrow).

also be performed to assess whether there is drainage of exudate from the sinonasal ostium. This endoscopy should also include careful examination of the middle nasal meatus for the presence of nasal sequestrae or inspissated pus, nasal conchal bulla disease, and/or fistulation into the sinuses.^{98,99} Sinoscopy is often helpful, given that it may possibly demonstrate normal alveoli and so suggesting that the sinusitis present is not of dental origin. The goal of these examinations is to definitively confirm whether any of the cheek teeth are diseased and need to be extracted.

Treatment

In the early stages, an anachoretic infection may remain confined to the apical periodontal area, and all the pulp horns (or the common pulp in immature cheek teeth) may remain vital. At this early stage of infection, antibiotic treatment (e.g., 2 weeks of antibiotics effective against anaerobic bacteria) may be effective, but no factual data are available on the efficacy of such antimicrobial therapy. Surgical curettage of the affected apex has also been used but if curettage damages the apical blood supply of the tooth it will definitely cause dental death and later pulp exposure, and possibly fracture of the tooth.

In longer-standing periapical infections, extraction (or endodontic treatment) of the affected tooth is required to resolve the clinical signs. Extraction of the long crowned (hypodont) equine cheek teeth is a major surgical procedure with many possible immediate and delayed sequel. As noted, radiographic

confirmation of the presence of cheek-teeth apical infection can be difficult and if any doubt remains concerning whether a cheek tooth is infected or not, conservative treatment and not extraction should be performed. These include antibiotic therapy for suspect mandibular or rostral (06–08) maxillary apical infections and maxillary sinus lavage and antibiotic therapy for suspect caudal (09–11) maxillary cheek teeth apical infections. Failure to respond to the above conservative therapy should prompt a further clinical, radiographic, and where possible, computed radiographic evaluation for dental infection and progression of imaging changes can be helpful. Only when definite evidence of dental infection is present should dental extraction be performed.¹⁰⁰

8. Extraction of Equine Cheek Teeth

Local Anesthesia

Maxillary Branch of the Trigeminal Nerve

The maxillary branch of the trigeminal nerve, which is sensory to all maxillary teeth, can be anesthetized most readily and with least complications by injecting local anesthetic into the extraperiorbital fat body in the pterygopalatine fossa and allowing it to diffuse to the maxillary branch of the trigeminal nerve.¹⁰¹ Following aseptic skin preparation beneath the caudal aspect of the orbit, a 5-cm needle is inserted immediately ventral to the zygomatic process between the middle third and caudal third of



Fig. 46. Minimally invasive transbuccal extraction of a maxillary tooth with a clinical crown fracture. A long elevator has been inserted through a trans-buccal cannula into the oral cavity and is directed under oral endoscopic guidance into the periodontal space around the diseased tooth. It can then be driven into this space in a controlled manner using a mallet, thus loosening the tooth. The black markings on the pony's face overlie the buccal branches of the facial nerve.

the orbit. The needle is directed in a rostro-medio-ventral direction and inserted 30–35 mm through the masseter muscle. A decrease in resistance is then detected as it enters the extraperiorbital fat

body. The needle is advanced 15–20 mm further and 20 ml of local anesthetic is inserted. It may take 20 minutes or so for the maxillary nerve to become anesthetized. This procedure anaesthetizes all of the ipsilateral maxillary teeth.

Inferior Alveolar Block/Mandibular Block

The inferior alveolar nerve, which is sensory to all mandibular teeth, can be anesthetized as it enters the mandibular canal via the mandibular foramen on the medial aspect of the ramus of the mandible. This procedure is usually performed by insertion of a long needle up the medial aspect of the mandible beneath the pterygoideus muscles to the intersections of lines drawn perpendicular to the lateral canthus and level with the occlusal aspect of the mandibular cheek teeth. A recently described technique uses a specialized instrument to perform this procedure *per os*.¹⁰² If excessive volumes of local anaesthetic are used or if the local anaesthetic is deposited too far dorsally, the lingual nerves can be anaesthetized and the horse can cause marked tongue self trauma, especially if allowed to eat before the tongue anaesthesia wears off, and particularly so if bilateral mandibular blocks have been performed.

Repulsion

The traditional method for extracting equine cheek teeth has been by repulsion of the diseased tooth under general anaesthesia. This procedure carries all of the inherent expense and risks of general anaesthesia and additionally is associated with a high level of postoperative complications. This is because much damage occurs to the local alveolar and supporting mandibular or maxillary bones during repulsion and the punch usually fractures the diseased apex of the infected tooth, often leaving apical fragments attached to the alveolus. Some studies have shown that more than 50% of cases of equine dental repulsion will require a second sur-



Fig. 47. Minimally invasive transbuccal extraction. Having loosened the affected tooth sufficiently, a solid part of the tooth is then drilled using a long, toughened drill bit inserted through the buccal cannula (left image is an intra-oral view of drilling of a fractured tooth). The drill hole is then tapped and a long bolt is screwed into the tooth transbuccally to allow further loosening of the tooth. The bolt is then used to withdraw the tooth from the alveolus into the oral cavity, where it is detached from the screw.

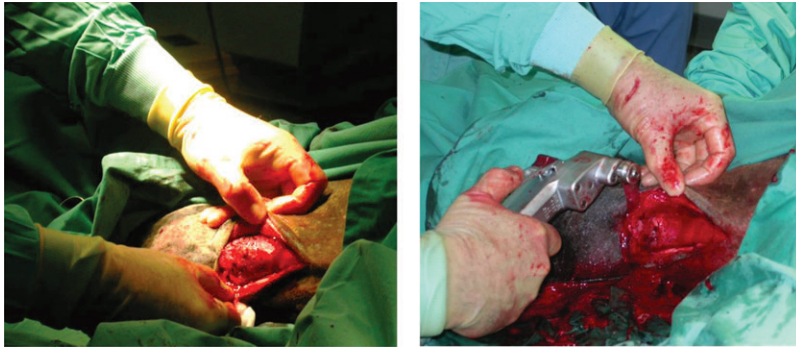


Fig. 48. The intraoperative image on the left shows a large osteosarcoma of the left mandible, previously diagnosed by a bone biopsy. On the right, the affected section of mandible is being completely resected. Bone plates were then used to stabilize the remaining mandible (with support from the contra-lateral mandible), which later healed slowly with a fibro-osseous union.

gery, often to curette dental fragments or alveolar sequestrae from infected, nonhealing alveoli.⁵⁷ Repulsion is no longer acceptable as a routine technique for equine dental extraction.

Lateral Buccotomy Technique

This technique involves a lateral surgical approach directly through the skin, subcutaneous tissues, and alveolar wall under general anaesthesia. In addition to requiring anaesthesia, it carries risks of marked intrasurgical haemorrhage, wound dehiscence, facial nerve paralysis, and parotid fistulation.¹⁰⁰ This technique should also not be routinely used for extraction, except possibly for cases of chronically infected cheek teeth that have developed large reactive cemental deposits over their apices (Fig. 41). Such apices with hypercementosis may become wider than the alveolus and so cannot be orally extracted. Alternatively, to extract such teeth with such expanded apices, an appropriate window can be made over the apex that is the reduced in size with a burr to allow oral extraction.

Repulsion or the lateral buccotomy technique are no longer acceptable as routine equine dental extraction techniques.

Oral Extraction of Cheek Teeth

This technique has the great advantage of being performed in the standing horse, and so removes the expense and risk of general anaesthesia. Additionally, it does not require surgery of the supporting bones and consequently, postoperative complications are less common than with more invasive exodontia techniques. The current availability of safe and effective sedatives and analgesics has been a major reason for the revival of the oral extraction technique, because the instrumentation has barely changed in over 100 years. In addition, local anaesthesia of the mandibular¹⁰², maxillary, or infraorbital nerves can also be used and the horse should be restrained in stocks and the head supported on a headstand or a head sling.

Extraction of Fractured Teeth

If the clinical crown is too damaged for oral extraction, or fractures during exodontia, extraction with fragment forceps may be possible. If enough crown is not present, and the tooth remnant is relatively loose it may be possible to extract it using specialized equine dental picks with varying head angulation and interchangeable heads.¹⁰³ More firmly attached dental fragments can be repulsed by use of a Steinman pin whose diameter needs to be inversely proportionate to the looseness of the dental fragment (Fig. 45). The recently developed, minimally invasive transbuccal extraction technique—using a small trocar through the cheek, having first identified the buccal nerves, and facial vasculature and catheterized the parotid duct, has proven to be very useful. The tooth is loosened with elevators inserted through the cannula and the use of a mallet. It is then drilled and extracted into the oral cavity using long drills and a long screw inserted via the cannula before being unwound from the screw and extracted *per os* (Figs. 46 and 47). In some infected teeth with a clinical crown fracture, the adjacent teeth drift toward it more occlusally and so prevent the (larger) reserve crown from being extracted. With such cases, a long motorized bur can be used to section the wider reserve crown and remove it piecemeal in the standing horse.

Endodontics

A number of workers have attempted to treat infected cheek teeth by use of endodontics (root canal therapy), which is complicated in horses by the length and multiple age-related and sometimes otherwise variable branching of the five to seven pulp horns in each cheek tooth. A major advantage of endodontics, if successful, is that the infected tooth is preserved and thus will then continue to erupt normally (at circa 2–3 mm/year). This prevents the development of overgrowths of the opposing cheek tooth and also “drifting” of the adjacent cheek teeth into the site of the extracted tooth.^{104,105} This latter “drifting” will eventually cause over-

growths on the caudal and rostral aspect of the opposing cheek teeth row.

Endodontic treatment can be performed through the apex of the tooth (*retrograde endodontics*), i.e., via surgical approaches through the mandibular or maxillary bones and via the apical aspects of the pulps, that requires general anesthesia—but this technique has shown poor long-term success.¹⁰⁶ More recently, endodontic approaches through the occlusal surface (*orthograde endodontics*) in standing horses has shown much more encouraging results.¹⁰⁷ A further novel treatment is to orally extract the affected tooth, immediately resect its apex, and then perform very thorough endodontic treatment from both its occlusal and apical aspects and re-implant the tooth into its alveolus. Peer-reviewed studies on orthograde endodontics and re-implantation have not yet been published.

9. Oral Tumors

Dental tumors can include noncalcified epithelial tumors (which are derived from the epithelium that forms enamel) which are termed ameloblastomas. They can also include a wide variety of calcified tumors from dentinal tissues (odontoma) or cement (cementoma) or combinations of all three dental components (compound odontoma or ameloblastic odontoma).⁷⁰ These usually present as slowly growing, hard, and usually painless focal mandibular or maxillary masses that are usually very radiodense. Depending on their size, these calcified dental tumors can usually be surgically removed and carry a good prognosis. Many types of tumors affect the supporting bones of the jaws including benign and malignant primary bone tumors (Fig. 48). A specific fibro-osseous growth of the rostral mandibular injury in younger horses has been previously noted.

Benign gingival growths such as different types of epulis, are common in other species but are rare in the horse. Squamous-cell carcinomas are the most common soft-tissue neoplasm of the equine oral cavity; they can occur at any site but have a predilection for the lateral margin of the hard palate adjacent to the caudal cheek teeth. At this site they may invade dorsally causing nasal or sinus neoplasia with secondary infection and looseness of the adjacent teeth. Such invasion is often very extensive before it is detected and complete surgical section is seldom possible. Radiotherapy, if available may be of value.

A wide range of other soft-tissue neoplasms may also occur as described by Knottenbelt and Kelly.⁷⁰ The prognosis depends on their size and how well defined they are to allow surgical excision, with generally a poor prognosis for advanced oral region soft tissue tumors.

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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.

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The Hormonal Basis for Reproductive Behavior in Nonpregnant Mares

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1. Introduction

At its most basic level, normal reproductive behavior that leads to mating and the successful production of offspring is essential for the preservation/perpetuation of all animal species. For free-roaming horses, social behavior and reproductive behavior are inextricably related, and both drive the day-to-day interactions among horses living in close proximity.¹ In contrast, the social and reproductive behavior of domestic horses are both heavily influenced by numerous management factors imposed on them.² For mares in performance settings, reproductive behavior is often viewed with disdain, ranging from a characteristic that is considered a simple annoyance, to behavior that, whether real or perceived, seriously impedes the ability of a mare to perform as intended. Because of that, it is common to attempt to control/eliminate normal reproductive behavior.³ The objectives of this review are to: 1) provide an overview of the hormonal basis for reproductive behavior in nonpregnant mares, and to put seasonal changes in the reproductive status of a mare and its attendant behavior into context that will aid the assessment of whether reproductive behavior is affecting a mare's performance activities; and 2) briefly discuss treatment options

for managing problematic reproductive behavior in mares.

2. Terminology

For this discussion, a brief review of the terms used to describe various reproductive events/states in the mare is warranted. The mare is defined as a long-day, seasonally polyestrous breeder. As a result of changing day length over the course of the calendar year, a nonpregnant mare will generally be in one of four reproductive states: 1) a noncycling, anovulatory state during the short days of winter, 2) an ovulatory state (i.e., "cycling") during the long days of the late spring and summer, 3) a spring "transitional" phase between the winter anovulatory and summer ovulatory states, or 4) a fall "transitional" phase between the summer ovulatory and winter anovulatory states.

By definition, winter anovulatory and spring transitional mares are not "cycling." In contrast, beginning in the late spring and continuing through the summer and into early fall, a normal nonpregnant mare should have repeating estrous cycles, each encompassing one interovulatory interval of approximately 21–22 days. Each estrous cycle is composed of a period of estrus (i.e., "heat") lasting approximately 1 week and a period of diestrus lasting ap-

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proximately 2 weeks during which time the mare is out of "heat." Estrus defines the period of time when the mare is sexually receptive to the stallion (i.e., will allow mating) and diestrus defines the period of time when the mare is overtly antagonistic to the stallion (i.e., refuses mating attempts). Estrous behavior refers to the signs displayed by a mare in estrus, whereas diestrous behavior refers to the signs displayed by a mare in diestrus. The clinical signs and hormonal basis for estrous behavior and diestrous behavior will be discussed later. In contrast with a cycling mare, a typical winter anovulatory mare is generally ambivalent in response to the presence of a stallion (i.e., neither showing signs of estrus or diestrus), although importantly as will be discussed later, some anovulatory mares display what is referred to as "paradoxical" or "unseasonable" estrous behavior that has important implications for assessing and managing reproductive behavior in performance mares. Of the two transitional phases, the spring transition is particularly relevant, due to the characteristic nature of reproductive behavior these mares exhibit, which will be discussed later.

3. Reproductive Physiology

Like other mammals, most reproductive processes in the mare, including behavior, are primarily, although not exclusively, regulated by the hypothalamic–anterior pituitary–ovarian axis. During the winter anovulatory period, the hypothalamic–anterior pituitary–ovarian axis is in a relatively quiescent/inactive state, whereas during the summer ovulatory period it has peak activity. During the spring and fall transitional phases, activity of the hypothalamic–anterior pituitary–ovarian axis is on an increasing and decreasing plane, respectively.

Gonadotropin-releasing hormone (GnRH) secreted from the neurons of the hypothalamus regulates secretion of the gonadotropins follicle-stimulating hormone (FSH) and luteinizing hormone (LH) from the anterior pituitary gland, both of which act systemically to regulate ovarian activity. FSH promotes growth of ovarian follicles, whereas LH induces maturation and ovulation of a dominant preovulatory follicle(s), which results in the formation of a corpus luteum (CL). The principle ovarian steroid hormones, estrogen produced by follicles and progesterone produced by the CL, are the predominant hormones regulating reproductive behavior, and as such, will be a major focus of this review. Another hormone integrally involved in the regulation of reproduction in the cycling nonpregnant mare is prostaglandin F₂ α (PGF₂ α), which is secreted from the endometrium of the uterus. Secretion of PGF₂ α causes luteolysis, the process through which function of the CL (i.e., progesterone secretion) ceases. As such PGF₂ α is responsible for ending one estrous cycle and initiating the subsequent cycle.

4. Seasonality of Reproduction

During the shortest days of the year (December and January in the Northern Hemisphere), 85–90% of nonpregnant mares are in the winter anovulatory phase associated with quiescence of the hypothalamic–anterior pituitary–ovarian axis. Clinically, these mares have small, firm ovaries with follicles <20 mm, and an atonic, flaccid uterus and cervix. Although the winter anovulatory phase is often referred to as "winter anestrus," that term is a misnomer given that some seasonally anovulatory (as well as some ovariectomized) mares will exhibit "paradoxical" or "unseasonable" estrous behavior that is caused by hormones secreted from the adrenal cortex.^{4,5} The intensity of this "false" estrous behavior has been judged to be equivalent to the behavior that cycling mares display during the initial and terminal days of estrus, but less intense than the behavior displayed near ovulation.⁴ Such behavioral receptivity to a stallion outside the ovulatory season that is independent of the hypothalamic–anterior pituitary–ovarian axis may have developed as a means of maintaining social bonds between a harem stallion and his mares.^{4,6} This phenomenon has important implications for how to manage estrous behavior in performance horses that will be discussed later. Importantly, approximately 10–15% of mares will continue to have regular estrous cycles through the winter, with signs of estrous behavior and the hormones controlling it the same as a cycling mare when the days are long.

As day length increases during the late winter/early spring (February and March in the Northern Hemisphere), mares go through a spring "transitional" phase associated with recrudescence of activity within the hypothalamic–anterior pituitary–ovarian axis. Initially, GnRH preferentially stimulates FSH secretion from the anterior pituitary gland, which causes a progressive increase in ovarian follicular activity that ultimately leads to the development of one to three anovulatory follicular waves typified by the formation of a large (>38 mm) dominant follicle that fails to ovulate due to insufficient levels of LH.^{7,8} The waxing and waning of follicular growth during the spring transition is associated with irregular and/or prolonged periods of estrous behavior, which is a hallmark of the spring transition. Once LH levels in the anterior pituitary gland have increased sufficiently,^{7,9} GnRH can cause a LH surge resulting in the first ovulation of the year which, by definition, marks the end of the spring transitional period and the start of the ovulatory season.

During the late spring and summer (April through September/October in the Northern Hemisphere), nonpregnant mares should be having regular estrous cycles. As noted previously, during the course of one complete estrous cycle mares will be in estrus for approximately 7 days. Estrus is characterized by growth of a dominant follicle at a rate of 3–5 mm/day until it reaches preovulatory size (gen-

erally >40 mm) and ovulates. The event of ovulation leads to the transformation (i.e., luteinization) of the follicular cells into a functional CL that begins secreting progesterone. Mares continue to show signs of estrus for 24–48 hours after ovulation, which corresponds with the length of time it takes for progesterone levels to rise high enough to block estrous behavior. The CL and its attendant production of progesterone keeps the mare in diestrus for approximately 14–16 days. It is important to note that during diestrus, mares can develop a dominant, preovulatory-size follicle (>40 mm); therefore, the presence of a dominant, preovulatory-size follicle by itself is not indicative that a mare is in estrus.¹⁰ In nonpregnant mares, CL function ceases after approximately 2 weeks as a result of the luteolytic effect of PGF 2α secretion from the endometrium, which brings the mare back into estrus of the new estrous cycle.

When day length decreases during the late summer and early fall, the hypothalamic–anterior pituitary–ovarian axis again becomes quiescent as mares enter the winter anovulatory phase. The fall transitional period is marked by increasingly irregular ovulatory activity that may be associated with spontaneously prolonged CL function (i.e., prolonged diestrus), which is followed by the complete cessation of ovulatory activity.^{11,12}

5. Hormonal Basis for Signs of Reproductive Behavior

Reproductive behavior in cycling nonpregnant mares is predominantly regulated by changing levels of the ovarian steroid hormones estrogen (from follicles) and progesterone (from a CL), which can have synergistic or antagonistic effects. For example, estrogen stimulates the formation of progesterone receptors (synergistic effect), whereas progesterone can down-regulate estrogen receptors (antagonistic effect).¹³ Of the two hormones, progesterone is the dominant hormone; a phenomenon readily demonstrated by the concurrent administration of both hormones to seasonally anovulatory or ovariectomized mares, which results in predominantly progestational effects.^{14,15}

During estrus, the progesterone concentration is at its lowest level, which has a permissive effect “allowing” estrogen of follicular origin to exert its effects physiologically and behaviorally. Estrogen promotes signs of estrous behavior that include standing still with a base-wide stance of the hind limbs, leaning toward stallion (or other stimulus), tail raised in a relaxed motion and held to one side, facial muscles and ears relaxed, and passing small amounts of urine frequently in association with eversion (“winking”) of the clitoris.⁶ In contrast, during diestrus and under the influence of progesterone, signs of diestrus behavior are displayed that include constant, agitated movement and switching of the tail; tense facial muscles with ears pinned back; may aggressively bite, strike, and/or



Fig. 1. Ultrasonographic image of the uterine horn of a mare in which endometrial edema is evident allowing discernment of individual endometrial folds.

kick at the stallion; may forcefully squirt urine; and may vocalize antagonistically toward stallion.⁶

In addition to their effects on mare behavior, estrogen and progesterone profoundly affect the physical (i.e., transrectally palpable) and ultrasonographic characteristics of the tubular genitalia. During estrus, the lack of progesterone allows estrogen to promote the development of endometrial (i.e., uterine) edema that can be readily appreciated with transrectal ultrasonography (Fig. 1) and gives the uterus and cervix a soft, “doughy” consistency. In contrast, during diestrus under the influence of progesterone, there is a lack of endometrial edema that can be readily appreciated with transrectal ultrasonography (Fig. 2) and gives the uterus and cervix a tight, toned consistency. Given the accuracy of ultrasonographic assessment of the presence or absence of uterine edema, it essentially serves as a reliable bioassay that is indicative of the hormonal state of the mare. As such, determining the presence or absence of uterine edema serves as an indirect method of estrous detection (i.e., uterine edema in conjunction with a soft, doughy uterus/cervix is indicative of the hormonal state of estrus and the absence of uterine edema in conjunction with a tight, toned uterus/cervix is indicative of the hormonal state of diestrus), and its use in that manner for mare breeding management is a common practice.

6. Assessing Whether Reproductive Behavior is Affecting Performance Activity

Based on a survey completed by over 750 veterinarians, Jorgensen et al¹⁶ reported that approximately

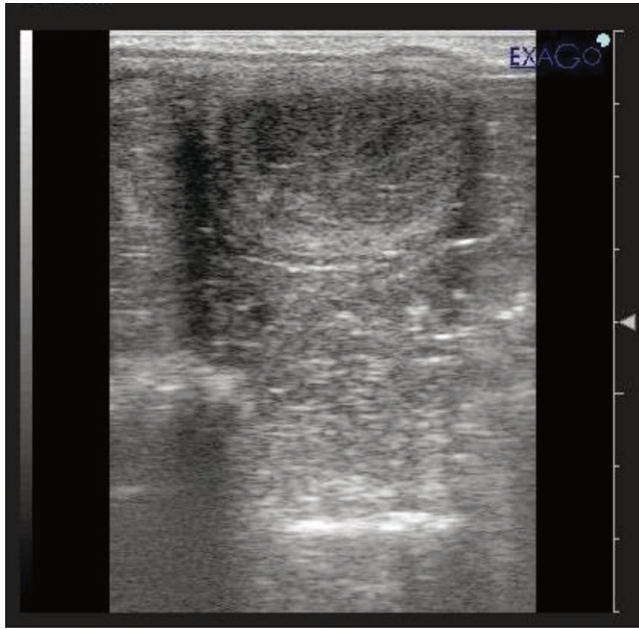


Fig. 2. Ultrasonographic image of the uterine horn of a mare without endometrial edema, which results in a homogeneous “ground glass” appearance.

90% of the veterinarians had the clinical impression that the estrous cycle affected the performance of mares. The most frequently reported clinical sign associated with an effect of the estrous cycle on performance was attitude change. Other signs included tail swishing, difficulty training, squealing, “horsing,” excess urination, kicking, and a decrease in performance. It is evident this list includes behaviors associated with both estrus and diestrus. In addition, it is important to note that some problematic behaviors displayed by mares that are thought to be associated with estrus are in fact not estrous behaviors, but signs of 1) submissive behavior, 2) urogenital discomfort, or 3) stallion-like behavior.^{17,18} Of these, submissive behavior may be most easily confused with estrous behavior. Submissive behavior includes leaning away from perceived threats, swishing/ringing the tail, and actively squirting urine, which collectively can give the impression of estrus.¹⁸ In contrast with submissive behavior, as noted previously, true estrous behavior includes leaning toward the stallion (or other stimulus), relaxed lifting motion of the tail, stationary/squatting stance, and passive urination (full stream or small amounts in spurts).

In an effort to evaluate the potential for an effect of stage of estrous cycle on the behavior of mares, Hedberg et al¹⁹ conducted two behavior tests (novel object and isolation) on 12 mares, once when they were in estrus and once during diestrus in a crossover design. Five of the mares served as controls, whereas the other seven mares were classified as “problem” mares based on their owner’s perception

of estrous-related behavioral problems. There were no significant differences in the behavioral responses between estrus and diestrus within the control and “problem” groups, nor were there differences in the behavioral responses between the two groups of horses; however, as the author’s note, the sample size was small and a crossover study design may not have been the most appropriate experimental design. Therefore, further work in this area is warranted.

Although it has not been conclusively documented in the mare, it is plausible that changing levels of estrogen and progesterone throughout the estrous cycle may influence nonreproductive body systems, such as the musculoskeletal system, as such effects have been observed in women throughout the menstrual cycle.²⁰ If estrogen and progesterone have differing effects on the musculoskeletal system in mares, it is plausible that a subtle lameness could be exacerbated at specific times during the estrous cycle and hence be an underlying reason for varying performance in a cycling mare. Clearly, this is an area that warrants further investigation.

When evaluating an owner/trainer complaint of an estrous cycle-related behavior/performance problem in a mare, the veterinarian should first determine whether the problematic behavior is or is not related to the reproductive status of the mare. First and foremost, a complete physical examination should be performed to assess whether a nonreproductive medical condition could be the underlying cause of the problematic behavior. If no contributing medical condition is identified, a careful assessment of the mare’s current and ongoing reproductive status is warranted in conjunction with careful recordkeeping by the owner/trainer in an effort to correlate the problematic behavior with specific/repeatable reproductive events/status over time.

An initial thorough transrectal reproductive examination should be performed to determine the palpable and ultrasonographic status/characteristics of the entire reproductive tract. Table 1 summarizes the typical characteristics of the reproductive tract associated with each seasonal phase of reproduction throughout the year. Based upon the physical/ultrasonographic characteristics the seasonal status of the mare should be evident. If there is doubt, a followup examination(s) can be performed. If the mare is not cycling, the problematic behavior would not be expected to occur in a “cyclic” manner. In contrast, if the mare is cycling, it becomes necessary to track the mare’s reproductive status serially over time (i.e., over the course of one or more estrous cycles). Ideally, this involves monitoring the mare with transrectal palpation/ultrasonography a minimum of two to three times/week for 3–4 weeks to ensure the mare is monitored through one complete estrous cycle. Because the presence/absence of uterine edema is an accurate indicator of the hormonal status of a normal cycling mare, the use of endocrine testing for progesterone and estrogen may

Table 1. Characteristics of the Reproductive Tract of Mares During: 1) the Winter Anovulatory Period, 2) the Spring Transitional Period, 3) the Summer Ovulatory Period and 4) the Fall Transitional Period

Reproductive State	Component/Characteristic of the Reproductive Tract			
	Ovaries	Uterine Tone	Uterine Edema	Cervical Tone
Winter anovulatory period	Follicles <20 mm	Flaccid	Absent	Flaccid
Spring transitional period	Follicles >20 mm with a progressive increase in number and size	Initially flaccid, then increasingly doughy with increasing follicular growth	Initially absent, then increasing with increasing follicular growth	Flaccid/soft
Summer ovulatory period: estrus	Follicle >25 mm, CL absent	Soft, doughy	Prominent, peaking around the time of ovulation	Soft
Summer ovulatory period: diestrus	CL present with variable follicular activity/size	Tight, toned	Absent	Tight, toned, closed
Fall transitional period				

Similar to cycling mare, but estrus/ovulation becoming more irregular

not provide any further diagnostic information; however, hormone levels (particularly progesterone) can be determined over time to have truly quantitative data.

When monitoring the reproductive activity of a cycling mare, it is important to consider that some mares experience pain in the peri-ovulatory period, that ranges from 1) increased sensitivity/pain during manual transrectal evaluation of the ovary, 2) sensitivity to weight and/or manipulation of the back, and 3) overt colic-like symptoms of pain.²⁰⁻²³ Of these, sensitivity during manual evaluation of the ovary is most common and does not warrant therapy or other intervention, given that it only occurs during transrectal manipulation of the ovulatory ovary. In contrast, mares that experience back pain and/or colic-like symptoms in the peri-ovulatory period may benefit from the use of ovulatory agents to reduce the time a large pre-ovulatory follicle is present on the ovary or they may benefit from suppression of cyclical reproductive activity.

If serial examination of the reproductive tract definitively identifies a particular reproductive state/hormonal status consistently correlates with problematic behavior, an appropriate course of action would be to pursue therapy that either: 1) blocks/inhibits the causative reproductive state/hormonal status and/or 2) mimics the reproductive state/hormonal status when the problematic behavior is *not* observed. Treatment options that are available for mimicking diestrus; prolonging diestrus; inducing and/or micking the winter anovulatory state; and mimicking and/or inducing estrus are summarized in Table 2. Because most treatment options involve the use of exogenous hormones, steps should be taken to ensure proper handling for the safety of all personnel involved with their use.³⁴ Although the use of an intrauterine glass ball (i.e., marble) to prolong diestrus is included in Table 2, it should be noted that their use has been called into question by recent reports of extremely deleterious reproductive consequences associated with them.³⁵ Regarding the use of exogenous progesterone/progestins for mimicking diestrus, efficacious products are noted in Table 2; in contrast, the following progestin formulations have been shown to lack efficacy: medroxyprogesterone acetate, hydroxyprogesterone caproate, melengestrol acetate, norgestomet, and various cattle implants containing progesterone.³ Therefore, it behooves the practitioner to use an evidence-based approach when attempting to regulate reproductive behavior.

7. Summary

Complaints and concerns about reproductive behavior interfering with performance activities in mares are common. Ideally, a careful and complete assessment of a mare's reproductive state/hormonal status (over time) should be performed to clinically determine whether there is a definitive, repeatable relationship between the reproductive

Table 2. Treatment Options for Addressing Problematic Reproductive Behavior in Mares

Desired Effect	Treatment Options	Treatment Details	Comments	Reference Citation(s)
Mimic diestrus	Altrenogest Progesterone in oil Long-acting progesterone	Administer 0.044 mg/kg orally, once daily Administer 100–150 mg IM, once daily Administer 1.5 g IM, once every 7–10 days	Potential for muscle soreness at injection site Potential for muscle soreness at injection site	Vanderwall et al ³ Vanderwall et al ³ Vanderwall et al ³
Prolong diestrus	Intrauterine glass ball (i.e., marble) Oxytocin	Place a sterile, 35-mm glass ball into the uterine lumen at time of ovulation Administer 60 units oxytocin IM once daily on days 7 to 14 after ovulation or administer 60 units oxytocin IM once daily for 29 days when treatment is started randomly during the estrous cycle (i.e., without knowing the day of ovulation)	Mare must be cycling. Risk of fragmentation and other serious problems such as pyometra Mare must be cycling	Vanderwall et al, ²⁴ Nie et al ²⁵ Vanderwall et al, ²⁴ Vanderwall et al ²⁶
	Induce a late-diestrus ovulation so new CL does not undergo luteolysis	Check mare for large (>35 mm) diestrus follicle on days 8 to 10 after ovulation, and if present, administer an ovulatory dose of human chorionic gonadotropin (hCG) and confirm ovulation	Mare must be cycling. Not all mares will develop a large diestrus follicle and ovulate in response to hCG	Vanderwall et al, ²⁴ Hedberg et al ²⁷
	Intrauterine infusion of plant oil	Infuse 1.0 mL fractionated coconut oil or peanut oil into the uterine lumen on day 10 after ovulation	Mare must be cycling	Vanderwall et al, ²⁴ Wilsher et al ²⁸
	Establish pregnancy and manually eliminate conceptus after maternal recognition of pregnancy	Breed mare using standard management techniques, confirm pregnancy, and then manually rupture the conceptus after day 16 after ovulation	Mare must be cycling. Terminating a normal pregnancy may be untenable to mare owner	Vanderwall et al, ²⁴ Lefranc et al ²⁹
Induce and/or mimic winter anovulatory state	Down-regulate hypothalamic-anterior pituitary-ovarian axis	Vaccination against GnRH	May result in permanent loss of reproductive function. Paradoxical estrous behavior may be problematic	Vanderwall et al, ³
	Bilateral ovariectomy	Surgical removal of both ovaries via colpotomy, laparoscopy or laparotomy	Not reversible. Paradoxical estrous behavior may be problematic	Hooper et al, ²² Kamm et al, ²³ Crabtree et al ³⁰ Nie et al ³¹
Mimic and/or induce estrous behavior	Abbreviate luteal phase with PGF2 α Completely abolish the luteal phase with PGF2 α Induce and/or mimic winter anovulatory state (see previous) and administer estrogen	Administer a single dose of 250 μ g cloprostenol or 10 mg PGF2 α IM after day 5 following ovulation Administer 10 mg PGF2 α IM twice daily on days 0, 1, and 2 after ovulation, and once daily on days 3 and 4 Administer 10 mg estradiol-17 β IM once daily or 5 to 10 mg estradiol cypionate IM once every 7 to 10 days		Coffman et al ³² Tibary et al ³³

state/hormonal status and a specific concern about the mare's performance activities. If there is a diagnosed relationship, an informed decision can be made regarding the most appropriate treatment(s) to eliminate the underlying cause of the problematic issue.

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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Can Ovariectomy Be Justified on Grounds of Behavior?

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1. Introduction

In practice, clinicians are commonly presented with mares reportedly behaving badly, either persistently or at regular or irregular intervals. This is often presumed by the owners and/or riders to be due to estrous behavior or due to their mare's reproductive hormone balance. Undesirable behaviors are varied and include the following: an unwillingness to respond to rider instruction or signals, bucking, rearing, overt reproductive behaviors, aggression, and stallion-like behavior.¹⁻⁴ It is assumed that when considering these behavioral problems, the behavior in question has been confirmed by the clinician to be temporarily associated with the estrus cycle be that estrus or diestrus, or with ovarian pain and not musculoskeletal, soft tissue, gastric, or dental pain. The question must also be refined to exclude those behavioral issues experienced due to the presence of a granulosa cell tumor³ or any other hormonally active neoplasia of the ovary.^{5,6} These criteria define the population of mares for the question: can ovariectomy on grounds of behavior be justified? The question is not an ethical one, rather whether or not behavior can be improved with surgical ovariectomy.

2. Search Strategy

The question forming the title of this presentation was first asked in 2014 as a critical appraisal of the

available evidence and was published in *Equine Veterinary Education*.⁷ The following portals and catalogues were searched: Pubmed/Medline (www.ncbi.nlm.nih.gov/pubmed), the University of Liverpool electronic library (www.liv.ac.uk.ezproxy.liv.ac.uk/library) and the International Veterinary Information Service (<http://www.ivis.org>). The search terms were "ovariectomy" AND "mare" AND "behaviour." Hand searching of references in all articles identified, and those within the author's knowledge, was also conducted. In addition, a request for references and opinions was made via a private worldwide equine reproduction email network. This research was repeated in January of 2017 and the results reported here.

3. Quantity of Evidence

Eleven, 28, and 27 papers were retrieved respectively; relevance screening was conducted based on abstracts and extended to entire manuscripts in cross referencing. This research identified four papers directly applicable to the question during the last 30 years.^{2,4,8,9} Of the four papers there was one randomized controlled trial⁹ and three retrospective studies.^{2,4,8} In addition, five papers were identified that yielded additional information.¹⁰⁻¹⁴

Author's Note – this paper is modified from *Equine Vet Educ* 2016;28(1):58–59. Adapted with permission.

NOTES

4. Quality of Evidence

The study by Hooper and coworkers⁸ looked retrospectively at 23 cases of bilateral ovariectomy between 1984 and 1990 by client survey. Of the 23 cases, 16 were for the purpose of behavior modification and seven were for other reasons not including ovarian pathology. Kamm and Hendrickson² reported the results of a retrospective study of 35 cases between 1996 and 2005 by client survey. The reported data included both bilateral and unilateral ovariectomy with the latter being due to ovarian pathology. Twenty-three mares had bilateral ovariectomy for behavioral problems. Roessner and coworkers⁴ reported results of a retrospective study of 20 cases of bilateral laparoscopic ovariectomy for the treatment of estrus-related or performance problems over an undefined period of time. Data was collected by telephone survey. The objectives of the study were to compare the behavioral improvement seen with altrenogest therapy alone to improvement after bilateral laparoscopic ovariectomy and to determine whether the behavioral or performance improvements reported with altrenogest therapy were predictive of the response to ovariectomy. These retrospective observational studies, based on client recollection and opinion, represent relatively weak evidence, are inherently biased, and do not address the possibility of a human placebo effect.

The study by Hedberg and coworkers⁹ primarily looked at the effect of adrenocorticotropic hormone (ACTH) (tetracosactide) on steroid hormone levels in five intact versus five ovariectomized mares. The mares acted as their own controls and the study was conducted in successive years (2003–2004). Of the parameters measured, estrous behavior was assessed by daily teasing with a stallion. Teasing behavior was assessed and scored using a standardized protocol. This prospective case-control design has greater evidentiary value than the retrospective study despite the relatively low numbers. Teasing scores, however, were not subject to statistical analysis and remained observational. This paper formed part of a greater work that looked at the adrenal response to ACTH between normal and “problem” mares.¹

Additional information was gathered from five papers describing surgical techniques for ovariectomy. Owner feedback and observations were included; however, characterization of the behavior patterns demonstrated by the mares prior to ovariectomy was either absent or incomplete and the owner feedback was not clarified or quantified.^{10–14}

5. Clinical Implications

Hedberg and coworkers⁹ demonstrated that ovariectomy resulted in continued displays of sexual receptiveness in all mares with a loss of normal cyclic activity. Ovariectomized mares showed more days of behavioral estrus compared with when they were intact; 44 days of behavioral estrus for all intact mares compared with 152 days for all ovariectomized

mares during the study period of 4 months (June–September). One ovariectomized mare showed 78 consecutive days of estrus. This finding is supported by the author’s experience and earlier published observations that ovaries are not essential for estrus behavior in the mare.^{15,16}

Hooper and coworkers⁸ reported that 35% of mares ovariectomized demonstrated continued estrus behavior. In 9% of cases this was judged to be objectionable by the owners. Of 12 performance mares, 10 were judged to be competing at greater-than-preoperative levels. In the report by Kamm and Hendrickson,² 22% of owners reported that they were either impartial or dissatisfied; mainly due to a failure of behavioral change following surgery. More generalized behavioral problems were more likely to be corrected following ovariectomy than more specific behavioral issues. Aggressive behavior and a generalized disagreeable demeanor were most commonly corrected (86% and 81%, respectively), followed by excitability (75%), kicking and biting (73%), and problems during training that related to estrous-like behavior (72%). Problems with other horses and frequent urination, interpreted by this author as more likely overt reproductive behaviors, were less likely to be improved after surgery (64%). These studies did not address the concept of ovarian pain as a cause of subtle behavioral issues encountered in ridden competition horses.

The report by Roessner and coworkers⁴ was interesting as it only included mares that had undergone treatment with altrenogest for a minimum duration of 2 weeks at “some time” before surgery. At least some reduction in objectionable behaviors had to have been observed with altrenogest treatment. This was suggested by the authors to support the diagnosis of an estrus-related behavioral problem. Primary estrus-related problems were defined as kicking, bucking or rearing (6/20); colic during estrus or ovulation (4/20); refusal to work during estrus (3/20); aggressiveness to other horses, people, or both (3/20); stallion-like behavior (1/20); undesirable estrus behavior during work (1/20); and flank pain during estrus (2/20). Some response was seen in all mares with altrenogest and ovariectomy was associated with a significantly better outcome than that of altrenogest therapy. The definition and frequency of responses were, however, not reported. It is assumed that not all responses were positive given the range and the Likert scale used. The responses in relation to the presenting behavioral problem were not reported. Six mares (30%) demonstrated estrus signs at least once postovariectomy and in four mares (20%) mild estrous signs persisted. It is important to note that the dosage of altrenogest reported in this study varied from 0.044 to 0.176 mg/kg and therefore one cannot rule out a direct “calming” effect at a higher (central nervous system [CNS]) level.¹⁷ This is supported by the fact that progestogens such as altrenogest are also often ef-

fective at curbing unwanted sexual or aggressive behavior in geldings.¹⁸ The report of Roessner and coworkers⁴ included two mares that demonstrated colic as a result of estrus or ovulation. This was established by the fact that this behavior was suppressed by treatment with altrenogest. It is the opinion of this author that mares may have palpably "sensitive" ovaries which can be related to undesirable behaviors, however it is important to note that follicular development and ovulation; therefore, the pain associated with this is not reliably suppressed by altrenogest at the standard dose. The study reported that four mares, with the owner observation of no noticeable improvement while on altrenogest, were excluded from the statistical analysis on the basis that the behavior was not associated with estrus or ovarian cyclicity. Further investigation of these mares would have been necessary to determine whether ovarian cyclicity and consequently ovarian sensitivity or pain were present while on altrenogest therapy. It should be noted that these mares did respond favorably to ovariectomy. In addition, one mare was reported to demonstrate stallion-like behavior and it should be noted that no endocrinological screening nor histopathological analysis of removed ovaries was part of the inclusion criteria; only ovaries of a palpably normal size, therefore ovarian neoplasia in the mares in this study cannot be ruled out.

Review of the five surgical reports retrieved the following owner observations post bilateral ovariectomy: Twenty percent of mares (1/5) demonstrated occasional manifestation of estrus¹⁰; in 67% (4/6) objectionable behavior was eliminated, and improvement reported in all mares¹¹; colic signs associated with estrus eliminated in 100% (2/2)¹¹; in 89% (16/18) objectionable behavior improved¹²; 100% (9/9) mare owners satisfied with the behavioral results in mares with unruly behavior and decreased athletic performance associated with estrus¹³; 75% (3/4) mares with aggressive behavior resolved and 25% (1/5) results did not meet their expectations.¹⁴

6. Clinical Message

The current data would suggest that if the undesirable behavior that prompts presentation is normal sexual (estrous) behavior then the likelihood is that ovariectomy will not correct the problem. In fact, ovariectomy may make the situation worse as estrous behavior may become irregular and/or persistent post surgery. It is not clearly understood why ovariectomized mares demonstrate estrogen-driven reproductive behavior, but it is often assumed to be due to estrogen of extragonadal origin with the most likely source being the adrenal gland. Asa and coworkers¹⁵ demonstrated that all of the 10 ovariectomized and 10 seasonally anestrous mares in the study demonstrated signs of behavioral estrus upon teasing with a stallion. All mares solicited copulation from stallions, were sexually attracted to them, and tolerated mounts, intromissions, and ejacula-

tions. It was suggested that the luteal ovary plays a controlling role in the inhibition of estrous behavior, with progesterone providing the mechanism for periodic inhibition of sexual behavior during diestrus. It was hypothesized that the adrenal gland was the most likely source of estrogen as in primate species.¹⁹⁻²² Phytoestrogens of dietary origin were acknowledged by Asa and coworkers,¹⁵ as a potential source of estrogen stimulation. Given that estrus is more vigorous than that observed in ovariectomized or anovulatory mares, it was hypothesized that additional steroidal stimulation is supplied by the ovarian follicles in the days just prior to ovulation. Further evidence of adrenal steroids stimulating sexual behavior was provided by a second experiment by Asa and coworkers,²³ who demonstrated suppression of behavioral estrus when dexamethasone was administered to suppress the adrenal gland. Despite this, the adrenal gland has not been associated with significant estradiol production.^{9,24} The steroidogenic enzyme aromatase cytochrome P450, which is responsible for the conversion of androgen to estrogen has been demonstrated to be present in the equine fetal adrenal gland,²⁵ but it is not known whether the same is true for the adult.

If the behavior is aggressive in character, then ovariectomy is more likely to be a successful therapy but the evidence for this is weak. Morganti and coworkers²⁶ demonstrated that serum cortisol was significantly higher in mares with elevated testosterone, suggesting that adrenal cortical activation in mares may result in increases in both serum cortisol and testosterone and that stress in mares may be associated with some aspects of aggressive or stallion-like behavior. It has also been demonstrated that ACTH treatment causes a significant increase in plasma levels of cortisol and testosterone in both intact¹ and ovariectomized mares.^{9,20} In a study by Dalin and coworkers,²⁷ it was noted that the most nervous mare in the study showed the highest adrenal testosterone levels, whereas the calmest mare, the lowest.

If ovarian pain, which may in the extreme case cause colic, is considered as a cause of abnormal or undesirable behavior, then ovariectomy may be indicated and curative; however, inducing ovarian inactivity via the use of a gonadotropin-releasing hormone (GnRH) vaccine may be a viable option that does not require surgery. Mares vaccinated against GnRH can however also demonstrate estrous behavior after ovarian inactivation.^{28,29}

Regardless of the reason for performing ovariectomy, it would be prudent to warn an owner of the possibility of intermittent or persistent signs of estrous behavior post ovariectomy. Future studies with accurate definition of the cause and characteristics of the behavior along with matched controls may enable a more definitive and comprehensive answer to the question.

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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Surgical Options for Ovariectomy

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There are a few commonly used methods for ovariectomy in the mare. Laparoscopic ovariectomy has become one of the most common methods and in many ways is the current standard of care. Most horses respond well to ovariectomy for behavioral issues. Author's address: 1678 Campus Delivery, Colorado State University, Fort Collins, CO 80523; e-mail: dean.hendrickson@colostate.edu. © 2017 AAEP.

1. Introduction

Reasons for Equine Ovariectomy

The main reasons for performing an equine ovariectomy include reducing inappropriate behavior, ovarian neoplasia, and the desire to stop the animal from becoming pregnant. There are at least three reports looking at the benefit of behavioral changes with laparoscopic ovariectomy. Ragle et al¹ reported on the benefit of behavioral change using ventral laparoscopic approach. In a retrospective study on 35 mares by Kamm and Hendrickson² in 2007, behavioral improvement was seen in 83% (19/23) of mares treated for behavioral-related problems. Aggression problems improved in 86% (12/14) of cases, general disagreeable demeanor improved in 81% (17/21), and excitability improved in 75% (12/16) of cases where these behaviors were previously observed. Kicking and biting improved in 73% (8/11), problems in training improved in 72% (13/18), and frequent urination and problems with other horses improved in 64% (7/11 and 9/14, respectively) of cases. Owners with nonovariectomized mares were also contacted to compare the normal progression of mare behavior over time to the behavioral change in ovariectomized mares. A statistically significant change in behavior of

ovariectomized mares over nonovariectomized mares was seen in the categories of decreased aggression ($P < .01$), decreased training problems ($P < .025$), decreased frequency of problem behaviors ($P < .001$), and improved overall behavior ($P < .01$). In cases where medical problems such as granulosa cell tumors, ovarian cysts, and cycle-related colic were treated with ovariectomy, all of the clients were very satisfied with the treatment, whereas clients attempting to treat cycle-related laminitis were dissatisfied.² In the third study, the authors found that bilateral laparoscopic ovariectomy was perceived by owners or trainers to be at least as effective as altrenogest administration with respect to diminishing a number of estrus-related behavioral and performance problems.³ In an abstract of a recent presentation, clients were 94% satisfied or very satisfied with the behavior changes in their horses after laparoscopic ovariectomy.⁴ In an unpublished study in dude string horses, the satisfaction rate was 100%. We find that more and more clients are opting for ovariectomy, especially with the ability to do it using a laparoscopic technique, in order to not have to deal with cycle-related behavioral issues. In the long run, it is generally less expensive than hormone administration. However, once the ovaries are removed, the horse cannot be used for reproductive purposes again.

NOTES

2. Methods for Equine Ovariectomy (Include Costs, Benefits, Complications)

There are many methods available for performing equine ovariectomies. These include traditional approaches such as standing colpotomy, laterally recumbent flank ovariectomy, and dorsally recumbent midline or paramedian ovariectomy. Although these techniques have been commonly used, they are rapidly being replaced by minimally invasive techniques such as standing-flank laparoscopic ovariectomy, laterally recumbent laparoscopic ovariectomy, or dorsally recumbent ovariectomy. This presentation will focus on minimally invasive techniques for equine ovariectomy.

Standing laparoscopic surgery reduces complications associated with general anesthesia, which reportedly causes death in 0.12–0.9% of equine patients.^{5,6} Laparoscopy requires multiple small incisions, with one to two incisions enlarged only enough to remove the ovary, thereby decreasing scar size and recovery time compared with other flank and ventral approaches. Although there has not yet been a large study looking at the complication rate of mares after standing laparoscopic ovariectomy, it is the author's impression that morbidity is very rare and that the most common complication is subcutaneous emphysema in the flank region and drainage and incisional dehiscence of the lengthened incision. The approach described by Dechant et al⁷ uses three 1-cm incisions on the right, two 1-cm incisions on the left, and one incision on the left side large enough to remove both ovaries. The surgery can be performed in less than 1 hour using a localized bilateral flank block and an epidural between the first and second coccygeal vertebra.⁷ Intraoperative pain can be decreased using a mesovarian injection of 10 mL of 2% lidocaine prior to operating upon the ovary.⁸ The mares are given 1.1 mg/kg flunixin meglumine IV pre- and immediately postoperatively and continued on either 1.1 mg/kg flunixin meglumine or 2.2 mg/kg phenylbutazone q 12 h orally for 4 further days. The mares are generally given only a single dose of procaine penicillin G IM prior to surgery.

Standing-Flank Laparoscopic Ovariectomy⁹

The horse is held off feed for 12 hours prior to surgery. When performing a bilateral ovariectomy, both flanks must be prepared for surgery. Six canulas are necessary for this procedure. The mare is sedated with detomidine and butorphanol to effect, placed in standing stocks, and a jugular catheter is placed. To maintain sedation, 20 mg of detomidine is placed in 1 L of IV fluids, connected to the jugular catheter, and given to effect. The flanks are clipped, aseptically prepared, and the portal sites are infiltrated with 10 mL of carbocaine each. The ventral two most portal sites in the left flank are connected with an additional 10 mL of carbocaine. The mesovarium should be infiltrated with 10–15 mL of local anesthetic prior to amputation. With

normal-sized ovaries, the ovarian pedicle can be ligated using ligating loops, ultrasonic devices, vessel-sealing devices, electrosurgery, lasers, stapling devices, or polyamide tie-raps. When using ligating loops, the mesosalpinx and the proper ligament of the ovary are sharply dissected to provide a smaller pedicle for ligation. Generally a shorter knot pusher is used in order to have a larger ligating loop to fit over the ovary. After amputation of the ovaries, the right ovary is passed under the small colon to the left side of the abdomen, and both ovaries are removed from the enlarged ventral-flank incision. In juvenile mares, it has been reported that the ovary can be amputated and dropped within the abdomen with no untoward effects. In cases of granulosa thecal-cell tumor (GCT) removal, only the flank of the affected ovary needs to be prepared as long as only one ovary is going to be removed. It can be difficult to use ligating loops on an enlarged GCT; consequently, a LigaSure^a device is generally recommended. It is possible to use a ligating loop on an ovary up to 18 cm in diameter, and to remove an ovary up to 25 cm in diameter using a LigaSure device. If the GCT has large cystic areas on ultrasound, it is possible to use an injection needle along with a suction device to remove cystic fluid, thereby reducing the size of the ovary. There have been a number of reports on the use of hand-assisted laparoscopy for ovariectomy. Although an enlarged incision is necessary for this technique, the eventual size of the incision is not dissimilar to the final incision for ovarian removal. This is especially true in the case of GCTs, and can be technically easier than a straight laparoscopic approach. Although GCTs are the most common disease process with enlarged ovaries, teratomas may also be present. Other techniques for removing large GCTs include morcellators and surgical pouches. It is the author's opinion that standing laparoscopic ovariectomy is easier to perform than while under general anesthesia given that the ovary hangs from the dorsal body wall. The horses are kept in a box stall for 2 weeks after surgery and then brought back into work. The cost for this procedure, including two nights in the hospital, is around \$1500.00. We do between 20 and 30 standing laparoscopic ovariectomies per year.

Laterally Recumbent Laparoscopic Ovariectomy

Laterally recumbent ovariectomies are performed in mares where only one ovary is to be removed. Generally, these mares have large GCTs. The mares are held off feed for between 18 and 24 hours, anesthetized, and placed in lateral recumbency. The portals are the same as for the standing flank laparoscopy. The ovarian pedicle is best transected with a LigaSure device. The incisions are enlarged and the ovary removed from the abdomen. The mares are placed in a box stall after surgery for 2–4 weeks depending on the size of the incision and then are brought back into work. The cost for this pro-

cedure is approximately \$2000.00. We rarely perform ovariectomy using this method in our hospital. The advent of the LigaSure device and greater experience in doing laparoscopy allow us to do most of these in the standing horse.

Dorsally Recumbent Laparoscopic Ovariectomy⁹

Dorsally recumbent ovariectomy requires general anesthesia and aggressive tipping into Trendelenberg position. Given that the horse will be tipped head down, tail up, they need to be held off feed for a longer period of time. Generally 18–24 hours is sufficient; however, putting the horse on a pelleted ration for 3–5 days may also be beneficial. It is recommended that the table be tipped at least 30° in order to move the abdominal visceral forward and away from the uterus and ovaries. It is vital to be able to do positive pressure ventilation for these horses under anesthesia. The ovaries and ovarian pedicles are not as accessible in a dorsally recumbent horse as they are in a standing horse. Two ligating loops per ovary, or a LigaSure device can be used to ligate and amputate the ovaries. One of the incisions, often the portal at the umbilicus, can be enlarged to remove the ovaries. The horses are placed in a stall after surgery for 4 weeks and then slowly brought back into work. The cost for this procedure at our hospital is around \$2000.00. We rarely perform dorsally recumbent laparoscopic ovariectomy, mostly due to surgeon's preference.

3. Outcomes After Ovariectomy

In general, clients and trainers are happy or very happy after laparoscopic ovariectomy as long as the procedure is done for behavioral issues. If there

are medical issues, such as cycle-related laminitis, the satisfaction rate seems to be much lower.

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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^aLigaSure, Medtronic, Lexington, KY 40504.

Behavior Problem: Ovaries or Not?

Sue M. McDonnell, PhD, CAAB

Our reproduction and behavior clinic's experience has been that for cases of behavior problems suspected to be related to ovarian function or dysfunction, systematic physical and behavioral evaluation in most cases reveals the root cause to be physical discomfort unrelated to normal ovarian function. Accurate diagnosis is important to successful resolution of the problem, with significant implications for horse welfare and client satisfaction. Author's address: Havemeyer Equine Behavior Lab, New Bolton Center, University of Pennsylvania School of Veterinary Medicine, 382 West Street Road, Kennett Square, PA 19104; e-mail: suemcd@vet.upenn.edu. © 2017 AAEP.

1. Introduction

Our veterinary school reproduction and behavior group regularly evaluates mares presented for behavior changes attributed to or suspected to be related to normal ovarian activity or pathology. In addition, our surgery group, when asked to perform ovariectomy for behavior or performance problems, routinely recommends evaluation by our reproduction and behavior team in advance of surgery. In the majority of such cases, results of systematic evaluation suggests that the root cause of the behavior or performance problem is discomfort unrelated to ovarian activity or pathology. In a subset of these, the severity of the problem behavior resulting from the root cause of physical discomfort is found to vary with normal ovarian function, such that the behavior problem is understandably misattributed to the ovaries. Using case examples, this presentation will describe our evaluation process and example diagnoses and resolution. The following comments and tables summarize what we feel are key aspects to systematic evaluation of such cases.

2. Obtaining a Detailed Behavior History

Summary terms often used to describe these mares, such as "bad," "marish," "difficult," "in heat," "aggressive," "studish," "hormonal," "horsing," or "resistant" typically suggest different clusters of behavior to different people. The most informative behavior history includes detailed description of the specific elements of the problem behavior and how the behavior varies over time and in various situations. This is most efficiently obtained directly from people working with the animal. Questions such as "What exactly does she do? What all is involved, her body, ears, tail, limbs, mouth? Can you predict when she is going to do it? Can you provoke the behavior? Can you interrupt the behavior? How is she with other mares, with geldings, or when exposed to a stallion? Is there any time she doesn't exhibit the behavior?" These are often helpful toward honing in on an unambiguous understanding of the problem behavior. In addition, questions concerning the mare's behavior in each season, particularly during winter when the ovaries are likely to be inactive, along with any available examination results on ovarian status and/or endocrine assays all are help-

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Table 1. Behavior of Estrus and Diestrus Compared to Behaviors Often Misattributed to Ovarian Function/Dysfunction

	Tail	Urination/Defecation	General Behavior	Posture	Leaning	Vocalization
Estrus	Off perineum, exposing vulva	Frequent urination with full estrus stance, prolonged bouts of clitoral eversion	Increased social interest and activity; approach males	Sawhorse mating stance	Toward stallion	Call to stallion
Diestrus	Down relaxed; clamped, agitated swishing if pressed	Ordinary urination frequency, volume & posture	Move away from/resist stallion; Squeal/kick/strike if pressed	Nothing unusual when not challenged; threatening if pressed	Away from stallion	Squeal or grunt if pressed
Androgen exposure	High when socially stimulated (male or female)	Stallion-typical elimination-marking behavior (investigation and covering of excrement, Flehmen, defecating in one area or along boundaries)	Socially animated, often described as "in charge," "headstrong," quick to bite, strike, kick; stallion-typical defecation pattern; sexual interest in mares; offensive aggression toward males	Arched neck, prancing gait when socially stimulated	If exposed to a mare in estrus, may lean into mare, arch neck while performing stallion-typical olfactory investigation	Stallion-typical calls to approaching mares or stallions; squeal and grunt vocalizations in close contact to males
Urogenital discomfort	Frequent lifting off perineum, swishing, without social pressure	Frequent urination or straining to urinate, prolonged bouts of clitoral eversion	Restless, gaze back toward caudal abdomen or udder area, "sour" or "crabby" with handlers or herd mates; sensitive to touch of caudal abdomen, flank	Frequent hind weight shifting, limb lifting and/or stamping/kicking out	Away from challenge; may press hindquarters and/or rub tail against walls or fences	May squeal during animated outbursts
Musculoskeletal discomfort	Agitated swishing, perineal slapping	Usually normal	Variable from continuously ill at ease to relatively normal; frequent limb lifting and weight shifting	Frequent weight shifting on limbs; frequent neck stretches; frustration head shaking	Usually none	Usually none
Abdominal discomfort	Swishing, slapping perineum	Usually normal	Restless, may gaze back toward and nuzzle abdomen	Frequent bouts of tongue extensions, lip licking	May press abdomen into walls	Squeal or grunt with sharp pain or animated outbursts
Submissive guarding (fear, pain)	Clamped, swishing, ringing	Squirting urine while clamping or swishing tail	Worried glassy-eyed facial expression and ear movements, hyper-reactive	Covering, tail tucked	Away from challenge	Squeal or grunt if extremely pressed

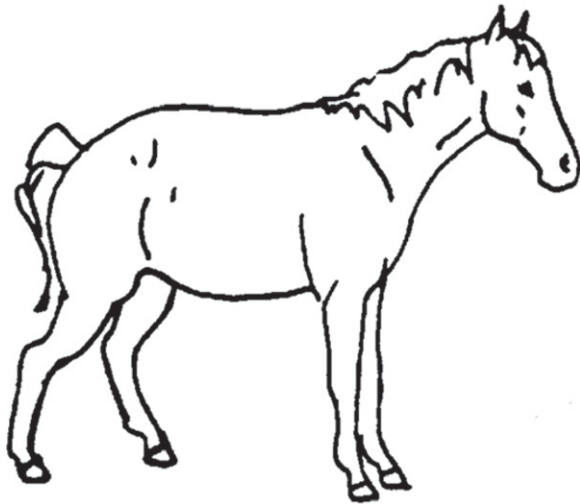


Fig. 1. Estrus posture.

ful. For example, if the problem behavior truly is behavior resulting from estrus, and it has continued during winter anestrus, then ovariectomy is not likely to improve the behavior, and may actually make matters worse.

When taking the history, observing examples of the problem behavior can be informative. Clients often can provide video-recorded examples of the problem behavior, and in some cases can reliably predict or provoke the problem behavior for direct observation.

Table 1 summarizes specific behavioral elements of estrus and diestrus compared with behaviors often misattributed to ovarian function or dysfunction. This rubric can be quite helpful for structuring discussion of the problem behavior history with clients and caretakers. In many instances, there is considerable misunderstanding of the specific elements of normal estrus, diestrus, and stallion-like behavior. Fig. 1, depicting the key postural elements of estrus, along with similar line drawings and photographs illustrating specific stallion-typical postures and behaviors as well as specific elements of stallion-mare interactive sequences can also be useful in this regard.¹

3. Making a Diagnostic Plan

In most of the cases we evaluate, the history suggests that physical discomfort may be either the root cause or a principal factor contributing to the problem behavior that should be ruled out before recommending interventions aimed at the ovaries. Table 2 summarizes the evaluations we consider. We find it most time- and cost effective to begin with a reproductive tract exam so that we know ovarian status at the time and can rule out any abnormalities or potential sources of urogenital discomfort. This is coordinated with a 24-hour videotaped sample of the mare for evaluation of behavioral

Table 2. Diagnostic Evaluations

24-hour video behavior evaluation
Scan for patterns of behavior suggesting discomfort; observe urination frequency, posture, stream; observe defecation pattern (male or female) and elimination marking behavior
Directly observe behavior in response to social challenges
Present feces from mare, stallion; observe response to estrus detection with stallion; observe response to estrus and diestrus mares
Reproductive tract examination
Palpation and ultrasound per rectum: ovarian activity, uterus, cervix
Speculum exam of vagina
Endocrine assays
Ovarian steroids, inhibin, anti-Müllerian hormone, testosterone as indicated to address stallion-type behavior
Abdominal ultrasound
As indicated by behavior findings (observed signs of discomfort)
Nuclear scintigraphy
As indicated by behavior and/or physical exam findings
Diagnostic analgesia trial with video behavior evaluation
As indicated by behavior and/or physical exam findings
Neurologic examination
As indicated by behavior and/or physical exam findings

signs of discomfort.^{2,3} For mares alone in a stall, animated bucking, kicking out, kicking walls, slapping the abdomen against walls or backing into or rubbing the hindquarters into walls or objects, self biting, pawing (other than in anticipation of feeding), and frequent frustration head shaking all are commonly misinterpreted as especially demonstrative estrus or diestrus, but more often are indications of physical discomfort. Squeal or grunt vocalizations, frequent urination or defecation, although normal responses to social provocation during various stages of estrus or diestrus, in the absence of social stimulation or pressure, also more often are the result of physical discomfort. In painful mares, these behaviors can also occur in response to any handling or social pressure, which can understandably complicate interpretation.

Depending on the finding of video behavior evaluation, various challenges can be arranged to confirm suspected conditions. For example, should the mare's behavior in her stall suggest male-type behavior, the mare's behavior in response to exposure to excrement of stallions or exposure to mares in estrus and diestrus or their excrement can be useful in confirming male-type behavior. Exposure to other mares or to stallions while observing the behavioral response of both the subject mare and the stimulus animal can also provide insight.

4. Example Diagnoses

Table 3 lists various abnormalities that were diagnosed as the root causes of objectionable behavior in mares where the problem behaviors had initially been misattributed to ovarian function or dysfunction.

Table 3. Example Diagnoses of Root Causes of Problem Behaviors Initially Misattributed to Ovarian Function/Dysfunction

Gastric ulcers
Gastric impaction
Enterolith
Intermittent impaction colic
Foreign body jejunal abscess
Uterine adhesions
Tense round ligament of uterus
Urethritis
Vaginitis
Pneumovagina
Vaginal lipoma
Vaginal-cervical developmental anomaly
Excessive vulvoplasty
Mastitis
Bladder adhesion
Strangulating abdominal lipoma
Abdominal adhesions
Uroliths
Musculoskeletal discomfort (neck, back, pelvic, limb)
Static-electricity sensitivity
Intersex-pseudohermaphrodite
Sleep deprivation
Head-shaker syndrome

tion. In some cases, two or more sources of discomfort were identified. For example, it is not uncommon for horses with musculoskeletal or caudal abdominal visceral discomfort to also have gastric ulcers, either as an independent condition or understandably secondary to the stress of the other discomfort.

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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How to Use Photodynamic Dye Therapy for Periocular Squamous Cell Carcinoma

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1. Introduction

Periocular squamous-cell carcinomas (SCC) of white skin of the eyelids can be a very frustrating condition that leads to loss of lid function and potentially the globe. If intervention is sought early in the process, there are many treatment options available, with the best option being highly dependent on the structures involved, and extent of the involvement. All too often, however, owners do not seek treatment for periocular SCC until the tumor is large and invasive enough that enucleation is the best option to remove sufficient tissue to achieve reasonable assurances of tumor resolution with clean margins. There are many adjunctive treatment options to combine with debulking of the tumor. Cryotherapy, injectable chemotherapy, topical chemotherapy, and hyperthermia have been reported with variable success rates. H-plasty can be successful in some instances to achieve clean margins of a lid tumor, but can have limitations if the tumor involves more than one third the length of the lid margin.

The use of photodynamic dye therapy (PDT) for squamous-cell carcinoma has been well described in humans and small animals.¹ For these species, the dye (verteporfin) is injected systemically, and the tumor is then exposed to the appropriate

light wavelength percutaneously for a deep tumor, or directly for a surface tumor. After injection, the dye is rapidly taken up by the remaining tumor cells. Light activation of the dye causes a release of free-oxygen radicals which results in cellular necrosis. For the horse, however, the dye is injected directly into the tumor bed after the majority of the tumor is debulked.^{2,3} The injected tumor bed is then locally exposed to the 690-nm light to activate the dye.

2. Materials and Methods

For PDT in horses, the patient is sedated with detomidine hydrochloride at a dosage of 0.02–0.04 mg/kg intravenously (Fig. 1). The base of the tumor is locally blocked with mepivacaine in sufficient volume to allow for debulking of the tumor down to surface level. A clean margin is not usually attainable. The goal is to reduce the tumor while creating a flat tumor bed for injection of the dye. The dye is then reconstituted and injected into the tumor bed. Most lesions are treated with 3.5 mg of verteporfin^a reconstituted with sterile water for injection to a volume that will allow all the dye to be injected into the tumor base. Care should be taken to avoid over diluting the dye such that there is too much volume that cannot be accommodated by the tumor base.

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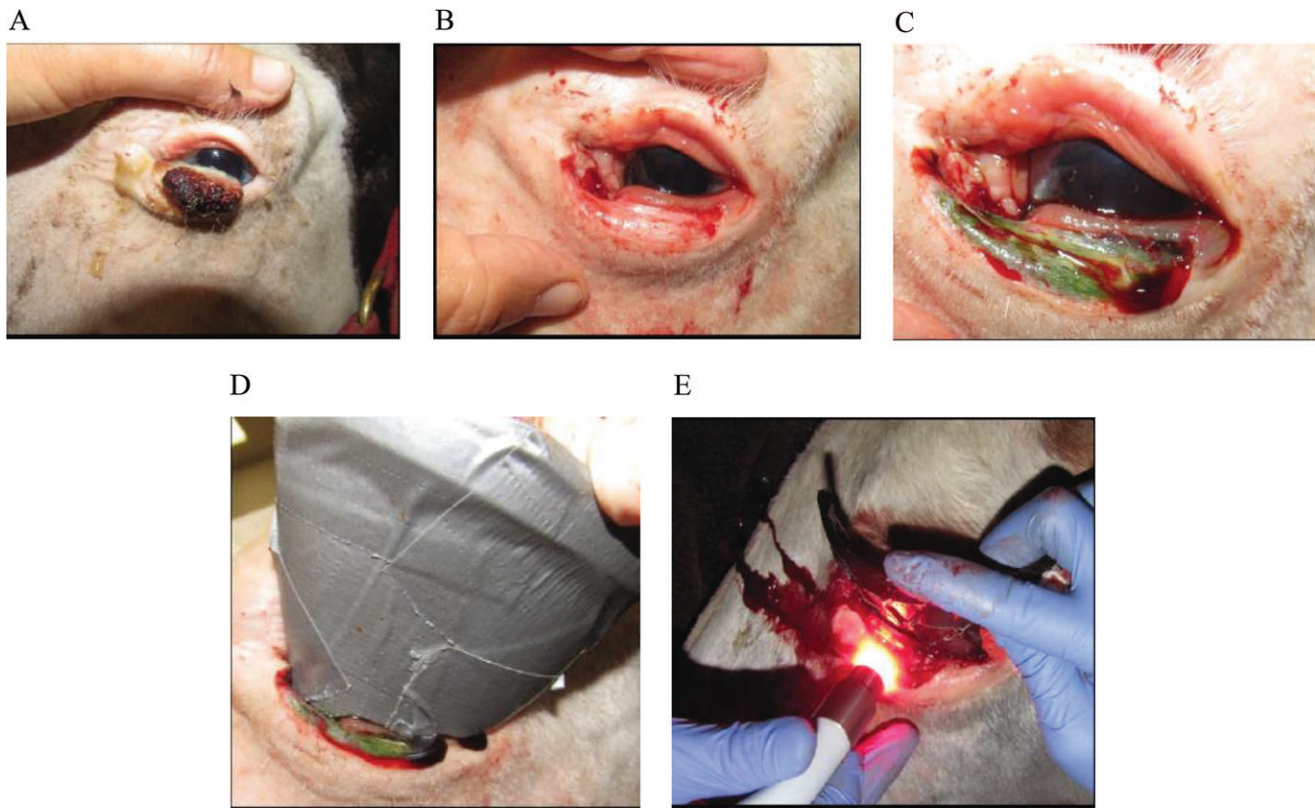


Fig. 1. This series of pictures shows the process from original tumor mass (A), debulked to surface level (B), the tumor bed after the dye has been injected (C), the shielded globe (D), and the light activation of the dye (E).

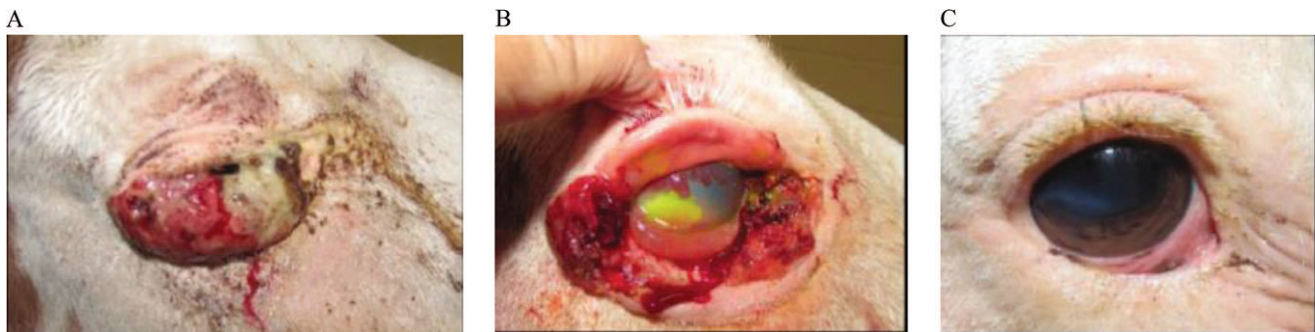


Fig. 2. Case No. 1: A shows a tumor that involved the entire lower eyelid and B is after debulking in preparation for PDT. The ulcer on the cornea was due to physical irritation of the tumor contacting the corneal surface. Image C was taken 4 months later.

With the globe protected with a Styrofoam shield covered in duct tape, a 690-nm visible red light is used to activate the dye within the tumor bed. The tumor bed is exposed to the light for 8 minutes per site. Multiple activation sites will be used based on size of the lesion. Note: The dye will continue to be activated by sunlight. Care should be taken to avoid extended light exposure. A fly mask with ultraviolet radiation (UV) protection and daytime stall rest is recommended for 7–10 days. Immediately post procedure, flunixin meglumine at a dosage of 1.1 mg/kg is administered intravenously and triple antibiotic ophthalmic ointment is placed in the eye. The treated area will swell significantly

and will have a thick ocular drainage for 5–7 days. Patients can be given flunixin meglumine orally as needed to control pain and swelling. Most patients do not require more than 2–3 days of NSAIDs. The discharge will resolve and owners can clean the area around the eye with warm wet cloths to remove the drainage.

3. Results

Remodeling of the tumor bed can take up to 4 months, and requires periodic rechecks and possible adjunctive therapy for complete resolution (Figs. 2–6).



Fig. 3. Case No. 2: A shows case No. 2 prior to PDT. B, 2 months after PDT, and C, 3 months after PDT. Eyelid margin continues to remodel, and may require additional adjunctive therapy to completely resolve.



Fig. 4. Case No. 3: A, pre PDT; B, 3 months post PDT. Still resolving and changing. Biopsies of current lid margin do not contain SCC cells.



Fig. 5. Case No. 4: A, admission and at the time of treatment. B, the dye has been injected into the tumor bed. C, 30 days post PDT. Complete resolution of this lesion was achieved by 3 months post PDT.

The average reoccurrence rate after cryotherapy is 9 months, whereas the published periocular SCC cases treated with PDT had no reoccurrence after up to 50 months.⁴

4. Discussion

PDT is an emerging option for invasive periocular SCC.⁵ Costs are variable depending on size and nature of the tumor. The major advantage to using

PDT is the reduced recurrence rate when compared with conventional adjunctive treatments, such as debulking, cryotherapy, and chemotherapy. Although the dye can be repeated multiple times for residual tumor, once is generally all that is necessary. If small amounts of tumor remain, those areas can generally be cleaned up with conventional adjunctive therapies.

PDT should be most successful if used for smaller lesions early in the process of lid margin invasion,

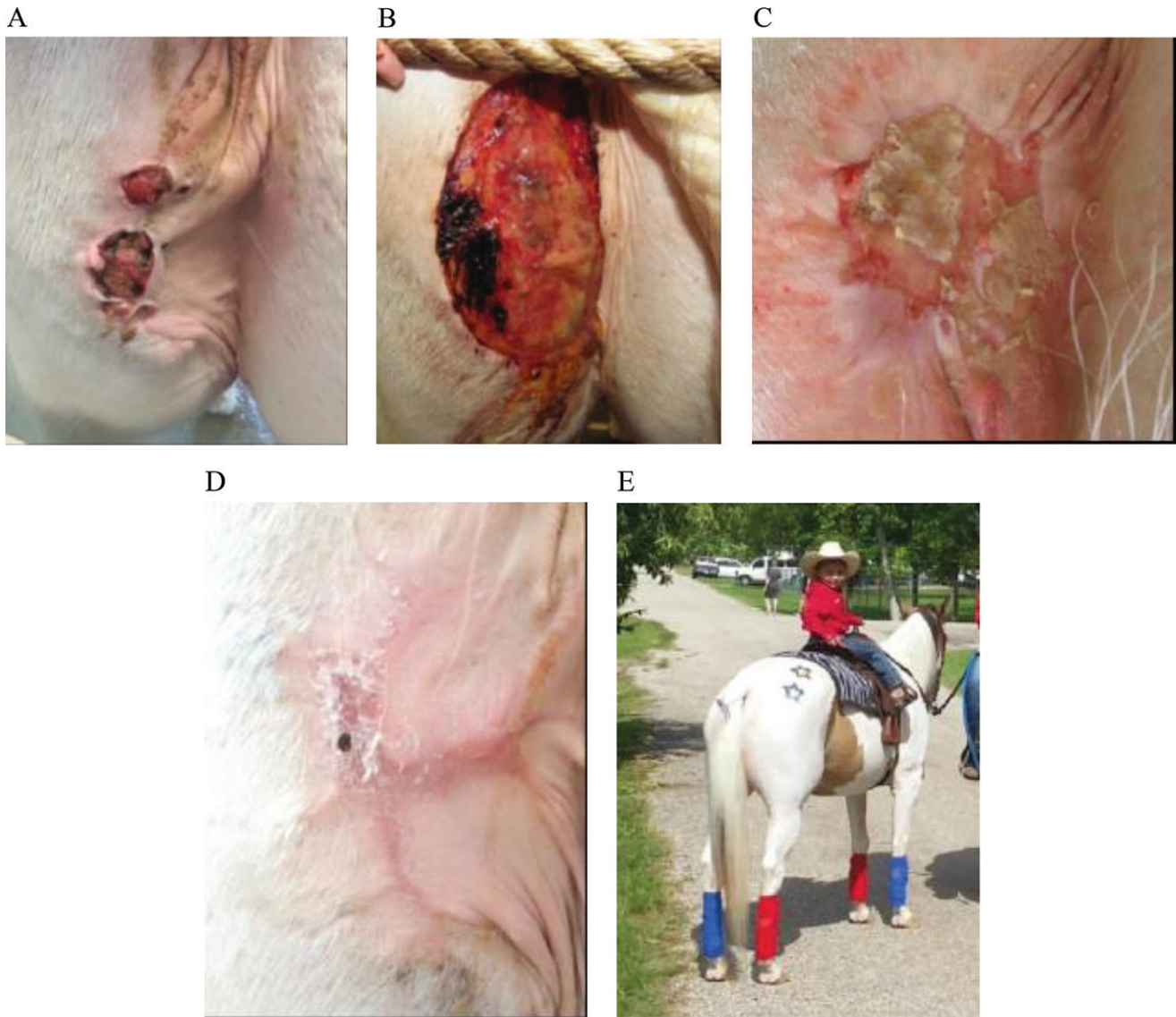


Fig. 6. Case No. 5: A perivulvar lesion. A, pre PDT and B, shortly after excision and 1 week after PDT. C, 2 months after PDT. D, 1 year post PDT. E, the small dark scab has since resolved completely.

but can also be considered for more extensive lesions as an alternative to enucleation.

Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Author has no conflicts of interest.

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*Verteporfin, Bausch & Lomb, Rochester, NY 14609.

Standing Ophthalmic Surgery—How to Perform Standing Surgery of the Periocular Region in the Field

Michala de Linde Henriksen, DVM, PhD, DACVO

Standing surgery of the periocular region in horses involves a set of clinical skills that are often needed by equine practitioners to treat common field conditions. Study of anatomy, instrumentation, and simple microsurgical techniques will enhance clinical outcomes. Preparation for surgery is important and involves sedation, patient restraint, head support, and prudent tissue handling. Practitioners should master the clinical skills that are needed to perform common procedures such as removal of eyelid masses, repair of eyelid lacerations, removal of the nictitans, and the tacking procedure for entropion. Placement of a subpalpebral lavage treatment system is another important clinical technique commonly used by equine practitioners to aid treatment of corneal ulceration in horses. Author's address: Colorado State University, College of Veterinary Medicine and Biomedical Sciences, Department of Clinical Sciences, Comparative Ophthalmology Service, 300 West Drake Road, 1678 Campus Delivery, Fort Collins, CO 80523; e-mail: michala.henriksen@colostate.edu. © 2017 AAEP.

1. Introduction

Surgery of the periocular area can be a challenge on anesthetized patients and an even bigger challenge for standing sedated patients. Nonetheless, standing surgery is often elected for equine patients in the field due to risk of placing a horse under general anesthesia in the field and financial considerations. Achieving a successful outcome when performing surgery in the ocular region is dependent on careful restraint of the patient that assures a steady head position, good analgesia that assures patient cooperation, and the application of best practice surgical principles when handling delicate periocular tissues. Appropriate choices for instrumentation, suture sizes, needles, and post-operative care are also very important. Handling periocular tissue incorrectly can lead to devastating complications to the eye, including

keratitis, corneal ulceration, trichiasis, and could end with an enucleation (Fig. 1).

The purpose of this paper is to explain how to prepare for standing surgery in equine ophthalmology patients. The proceedings will also cover the most common periocular surgeries that are done on the standing horse in the field. With study and practice, equine practitioners can achieve excellent results when performing these simple standing periocular procedures. However, referral of ophthalmic patients to a veterinary ophthalmologist with equine experience is recommended if the presenting ophthalmic disease extends beyond clinician expertise and/or comfort level and the owner is willing to refer.

2. Sedation, Restraint, and Preparation of the Patient

Adequate sedation of the patient is important. Depending on the surgical procedure, the horse will

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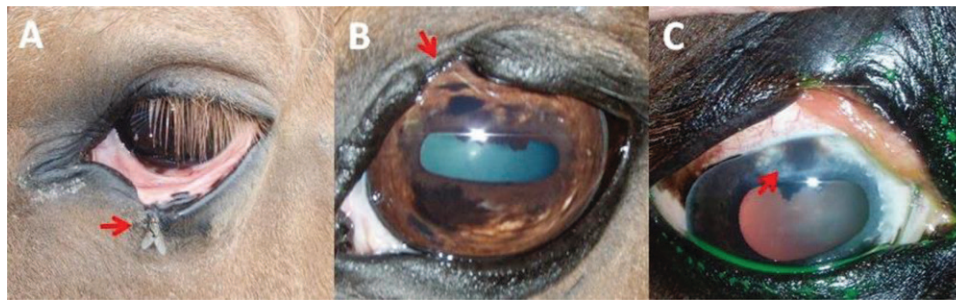


Fig. 1. Complications of eyelid lacerations in horses. A, An eyelid laceration of the lower eyelid was not correctly apposed in this horse. As a result, a divot of the lower eyelid caused the horse to have ectropion with high risk of corneal ulceration and conjunctivitis (red arrow). B, Another horse where an upper eyelid laceration (red arrow) was not correctly apposed, leaving the horse with a large divot in the eyelid which exposes the cornea, causing keratitis and risk of corneal ulceration. C, A horse with keratitis of the dorsal aspect of the cornea (red arrow) due to incorrect apposition of an upper eyelid laceration. (Photographs courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)

need to be sedated for 1 to 2 hours, including preparation time, clipping, and cleaning. Detomidine hydrochloride^a at a dose of 0.01 to 0.02 mg/kg (10 mg/mL IV solution) is the best intravenous sedative for standing equine periocular surgeries. If the horse needs to be resedated during surgery, additional intravenous detomidine doses of 0.005 to 0.01 mg/kg are usually effective to supplement the initial dose. In surgeries where a need for prolonged anesthesia is expected, acepromazine maleate^b at a dose of 0.02 to 0.05mg/kg (10 mg/mL IV solution) can be administered intravenously in addition to detomidine. Acepromazine should be given 15 to 30 min before surgery due to slow onset of action and should be used with caution, especially in stallions and geldings due to risk of penis protrusion and entrapment (Table 1).^{1,2} Intravenous butorphanol tartrate^c at a dose of 0.01 mg/kg (10 mg/mL IV

solution) can be used in addition to detomidine for pain control and longer-lasting sedation but this drug can cause uncontrolled head movements and is not often used for standing periocular surgeries.^{1,2}

It is important to have one or two assistants while doing the surgery. One assistant will be standing on the opposite side of the horse steadying the head. The horse's mandible will need to rest on a table made of hay or shavings bales or another solid support such as a rolling bin or equine dental headstand (Fig. 2). The head should be placed so that the surgery site is at the correct height for the clinician to perform the surgery without standing in an abnormal position. A second table with a sterile surface should be nearby. Surgical instruments are laid out on this table to make them easily accessible and keep them as sterile as possible. An assistant can open sterile instruments and suture material

Table 1. Sedation Guidelines

Sedative	Trade name	Dose	Re-dosing dose	Comments
Detomidine hydrochloride	Dormosedan 10mg/ml IV solution	0.01 mg/ml IV	0.002–0.005 mg/ml IV, 1–3 times with 15–30 min in between	<ul style="list-style-type: none"> ● Good sedative for standing periocular surgeries
± Butorphanol	Torbugesic 10 mg/ml IV solution	0.01 mg/ml IV	No	<ul style="list-style-type: none"> ● Longer lasting sedation when added to Detomidine sedation ● Can cause uncontrolled head-movements during surgery and is therefore not always recommended
± Acepromazine maleate	Acepromazine 10 mg/ml IV solution	0.02–0.05 mg/ml IV	No	<ul style="list-style-type: none"> ● Longer lasting sedation when added to Detomidine sedation ● Should be given 15–30 min before surgery start due to onset of action ● Can cause penis protrusion and entrapment in stallions and geldings



Fig. 2. The position of the head is very important when performing standing ophthalmic surgery on the periocular region. The head should be as stable as possible—hay or shavings bales are useful for mandibular support. (Photograph courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)

during the surgery, as well as check the sedation status of the horse. Good illumination is very important when handling the periocular tissue and placing small sutures. A surgical lamp, an office table lamp, or a headlamp can be used for proper lighting (Fig. 3).³

No horse will cooperate for surgery of the periocular and ocular region without adequate pain control. Local analgesia is delivered using injectable lidocaine^d (1% to 2% injectable solution) and/or bupivacaine^d (0.25% injectable solution) in the area of



Fig. 3. Good surgery light is important when using small suture and needle sizes to work on delicate periocular tissue. A headlamp is a useful tool for standing periocular surgery. (Photograph courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)



Fig. 4. An auriculopalpebral nerve block should be used before periocular surgery in the horse. The block is performed with 1–2 mL of local anesthetic using a 25-gauge 5/8 in. needle. The yellow line shows the path of the facial nerve and three different sites where the auriculopalpebral nerve block can be performed: 1) Where the facial nerve runs over the zygomatic arch caudal to the bony process of the frontal bone. It is easy to palpate the nerve here and this site is commonly used for injection. 2) Dorsal to the highest point of the zygomatic arch. The nerve is more difficult to palpate but this site accesses more branches of the nerve and may be more effective than the first site. 3) Caudal to the posterior ramus of the mandible at a depression at the most ventral aspect of the ear where the caudal border of the coronoid process of the mandible meets the zygomatic process of the temporal bone. This injection site is useful when the horse has a skull fracture or other abnormality that will not allow palpation of the nerve. (Photograph courtesy of Dr. Christie Wards, University of Minnesota.)

the surgical site. Lidocaine will give a fast onset of action and last for about 1 hour, whereas bupivacaine will have a slower onset of action but last for 3 to 10 hours.^{4,5} An auriculopalpebral nerve block should be used in all periocular surgeries and procedures (Fig. 4). Depending on the surgery or procedure, other ophthalmic nerve blocks (e.g., supraorbital nerve block [Fig. 5]) and local ring and/or line blocks can be used.

Auriculopalpebral Nerve Block

Strong eyelid muscles make horses good at closing their eyes, which complicates standing periocular surgery. It is necessary to block the orbicularis oculi muscle that is responsible for part of the eyelid closure to prevent or decrease blinking. An auriculopalpebral nerve block causes temporary loss of

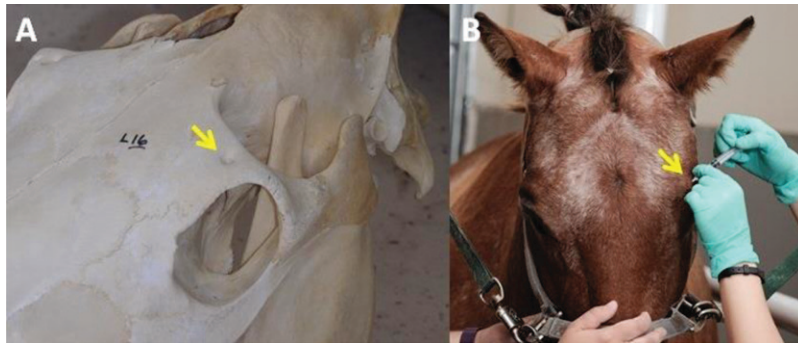


Fig. 5. The supraorbital nerve block will cause analgesia of the frontal nerve, which provides sensation to the upper eyelid. A, The frontal nerve (trigeminal nerve—sensory) exits the skull at the supraorbital foramen located above the orbital rim in the frontal bone (yellow arrow). B, The supraorbital foramen is palpated and a 25-gauge 5/8 in. needle is placed in the subcutaneous tissue above the foramen to inject 1–2 mL of local anesthetic into the tissue. (Photograph B courtesy of Dr. Christie Wards, University of Minnesota.)

facial nerve (CN VII) motor function that innervates the orbicularis oculi muscle. The block is performed using a 25-gauge 5/8-in. needle to inject local anesthetic into the subcutaneous tissue above the nerve. Three different areas can be used for the injection site (Fig. 4).^{5,6}

Supraorbital Nerve Block

The supraorbital nerve block abolishes sensation to the upper eyelid by blocking the frontal (supraorbital) nerve, which is a branch of the trigeminal nerve (CN V). This block is useful for upper eyelid surgeries and procedures involving the cornea or nictitans. It is most commonly performed with a 25-gauge 5/8-in. needle and 1–2 mL of local anesthetic that is injected into the subcutaneous tissue above the supraorbital foramen (Fig. 5). Clinicians should avoid inserting the needle into the foramen as this can damage the blood vessels or nerves exiting the foramen.^{5,6}

Line Blocks for Periocular Surgeries

The supraorbital nerve block will only block the sensation of the upper eyelid. Line blocks for other sensory nerve branches of the trigeminal nerve are useful, especially when surgery to the lower eyelid is needed. The zygomatic nerve, which is a branch of the trigeminal nerve that innervates most of the temporal aspect of the lower eyelid, can be blocked with a line block along the ventrolateral orbital rim.⁶

Preparation for surgery begins with preparing the tissues involved. Unless the horse has a long winter coat, clipping the surgery site is not usually necessary. If clipping is required it should be done with caution as some horses respond poorly to the clipper noise while under standing sedation. Insertion of cotton balls in the ears can be a useful aid as long as they are removed after surgery. Trimming the eyelashes for repair of eyelid lacerations is recommended given that the eyelashes can be difficult to differentiate from a black Nylon 4-0 suture. Alcohol and chlorhexidine should never be used to

clean the surgical site as these liquids are irritating to the cornea. Betadine scrub preparations also contain alcohol and should not be used for cleaning of the periocular or ocular tissue. It is recommended to use a 2% to 5% solution of dilute betadine solution that is the color of strong tea to clean the surgical site, then rinse the tissue with sterile saline (Fig. 6).^{5,7} This concentration of betadine solution is safe to use on the ocular surface and conjunctiva as well as the skin. Surgical drapes are not necessary for standing periocular surgeries as they will scare the horse more than they help with sterility, and towel clamps cannot be used to fix drapes to the skin in the awake horse. The equine halter can be covered with sterile towels to collect hemorrhage and provide a sterile surface below and/or around the surgery site.



Fig. 6. Correct preparation of the surgery site is important—never use alcohol, chlorhexidine, or betadine scrub in the area of the eye but instead use a diluted betadine solution (2% to 5%)—the color of a strong cup of tea (white arrow) followed by sterile saline.



Fig. 7. Correctly sized surgery instruments are important when handling periocular tissue. 1) Small needle holder (e.g., Derf needle holder). 2) Small forceps (e.g., Adson tissue forceps). 3) Bishop Harmon forceps. 4) Stevens tenotomy scissors (curved). 5) Metzenbaum scissors (curved). 6) Small suture scissors. 7) Allis tissue forceps. 8) Hemostats (curved). 9) Scalpel blade holder for No. 15 blade and scalpel blade No. 15. 10) Small towel clamps. 11) Histopathology cassettes.

The tetanus vaccination status of the horse should be determined before any standing surgery. According to the AAEP's Core Vaccination Guidelines, a tetanus toxoid booster should be administered before surgery if status of vaccination is not current or is unknown.⁸

3. Periocular Surgery Pack Instruments

Having the correct instruments is another important aspect of preparation for surgery of the periocular tissue. The large needle drivers and tissue forceps with large-sized teeth used for many other equine surgical procedures are not recommended as they can damage tissue and bend delicate small needles, predisposing to complications.^{9,10} A surgical pack for periocular surgeries should include the following instruments (Fig. 7):

1. **Small needle holder (e.g., Derf needle holder):** The importance of a correct-size needle holder cannot be overemphasized. The large needle holders used in equine practice will bend the small needles used in periocular surgery, making it impossible to place the needle in the correct position and causing excess tissue trauma. The author recommends the use of a Derf needle holder for sutures of 3-0 to 6-0 diameter.
2. **Small forceps (e.g., Adson tissue forceps):** Periocular tissue is very delicate. The conjunctiva will become edematous and eyelid margins may necrose if mishandled. The author recommends two different forceps for an ophthalmology pack. The first is an Adson tissue forceps with 1 × 2 mouth teeth that can be used for handling the third eyelid.

3. **Bishop Harmon forceps:** The second forceps in the ophthalmology pack should be a Bishop Harmon forceps with 0.5- or 0.8-mm teeth. This forceps is used to manipulate eyelid tissue (0.8 mm) and the conjunctiva (0.5 mm). Bishop Harmon forceps are never used to handle the suture needle during ophthalmic surgeries as the Bishop Harmon forceps teeth will be destroyed and the forceps will be bent and no longer appose.⁷
4. **Stevens tenotomy scissors (curved):** These small scissors can be used to remove small eyelid masses or trim small amounts of tissue from the margins of an eyelid laceration.
5. **Metzenbaum scissors (curved):** Metzenbaum scissors are longer than Stevens tenotomy scissors and are useful to remove the third eyelid or for dissection around the globe during enucleation (note: enucleation surgery is not described in this proceeding).
6. **Small suture scissors:** Surgical scissors should be used to remove sutures since this will dull scissors designated for cutting tissue. Small suture scissors are used to cut sutures during surgery and to remove skin sutures after 10 to 14 days.
7. **Allis tissue forceps:** Two Allis tissue forceps are used for third eyelid removal or to elevate the third eyelid to look for foreign material on the posterior aspect of the third eyelid.
8. **Hemostats (curved):** Two small Mosquito and two medium Kelly hemostats are used for hemostasis during various procedures as well as for third eyelid removal.



Fig. 8. Magnifier loupes are recommended when performing surgery on small eyelid masses or placing small sutures. The loupes can also be used when collecting cytology samples (Photograph courtesy of Dr. Christie Wards, University of Minnesota.)

9. **Scalpel blade holder for No. 15 blade and scalpel blades No. 15.**
10. **Small towel clamps:** Four to eight small towel clamps are used to hold the towels on the equine halter.
11. **Histopathology cassettes:** Histopathology cassettes are used for small tissue samples that will be submitted for histopathology. Larger tissue samples can be submitted in a formalin container but smaller samples can become lost if they are not enclosed in a cassette.
12. **Head loupes (e.g., Optivisor; Fig. 8):** Reasonably priced 4× or 7× binocular magnifier loupes^e can be obtained on-line. Magnification facilitates removal of eyelid masses and placement of fine-gauge suture.
13. **Surgery lamp (Fig. 3):** Surgery illumination can come from a surgery lamp, office table lamp, or from a headlamp attached to the loupes or on a band around the surgeon's head. Headlamps used for dental work may also be suitable for periocular surgery.

4. Suture Choice

Selection of the correct-size suture and needle point is important for periocular surgery. Corneal ulcerations can result if suture diameter is too large. Suture rupture and wound dehiscence can result if the suture is too thin. Fine gauge 4-0 **Nylon suture** with a P3 reverse cutting needle^f is recommended for suturing skin. The P3 needle is a premium reverse cutting needle that is often used for plastic or cosmetic surgery. It has a 3/8 circle diameter and the micropoint tip has a triangular shape geometry that is nicely sized for placing a figure-eight suture in the eyelid margin. The author favors 3-0 to 4-0 **Vicryl** suture with a P3 re-

verse cutting needle^f for suturing subcutaneous tissue given that Vicryl is an absorbable suture that will reabsorb after 30 days.¹¹ Larger gauge 2-0 Nylon suture with a straight cutting needle^f is recommended for securing the tabs that accompany placement of subpalpebral lavage (SPL) system.

5. Tissue Handling

Periocular tissue is delicate and must be handled with care. The importance of having the correct-size instruments for periocular surgery cannot be overemphasized as applying too much pressure to the tissue with a forceps with large teeth will cause tissue necrosis and poor healing. A Bishop Harmon forceps with 0.5- or 0.8-mm teeth is an appropriate instrument for handling equine periocular tissue as the forceps teeth are small enough to minimize pressure necrosis on eyelid tissue (0.8 mm) and conjunctiva (0.5 mm), but large enough to lift up any tissue that should be investigated. Smaller Bishop Harmon forceps with 0.3- or 0.12-mm teeth are too small for many of the periocular surgical procedures performed in a standing horse.

Many equine periocular surgeries require manipulation of the third eyelid, which can be challenging given that globe retraction causes unpredictable third eyelid movement, and much of the nictitans is seated deep in the nasal canthus. If a Bishop Harmon forceps that has 0.8-mm teeth is used to evert the nictitans, tissue damage can occur during retraction. An Adson tissue 1 × 2 teeth forceps is useful for examination of the posterior surface of the third eyelid, and an Allis tissue forceps can be used for manipulation of the nictitans during third eyelid removal surgery.

When working on skin near the eyelid margin, it is important to avoid gripping the periocular skin tissue given that this can cause necrosis of skin margins and poor healing. It is safer to grasp the palpebral conjunctiva when a section of skin must be moved given that this tissue is resilient due to an abundant blood supply.

6. Common Ophthalmic Surgeries/Procedures Performed on Standing Horses

Removal of Small Eyelid Masses

Small eyelid masses including squamous cell carcinomas (SCCs), sarcoids, or conjunctival masses (e.g., melanoma) can be removed from a standing sedated horse with either a triangular wedge-shaped resection or "house-shaped" resection (Fig. 9). As a general rule of thumb, only eyelid masses smaller than one third of the eyelid margin diameter can be removed with these two procedures. If more tissue/eyelid margin should be removed, the horse will require general anesthesia for blepharoplasty.¹² Blepharoplastic surgeries are complex procedures that should be performed by a board certified veterinary ophthalmologist or veterinary surgeon.

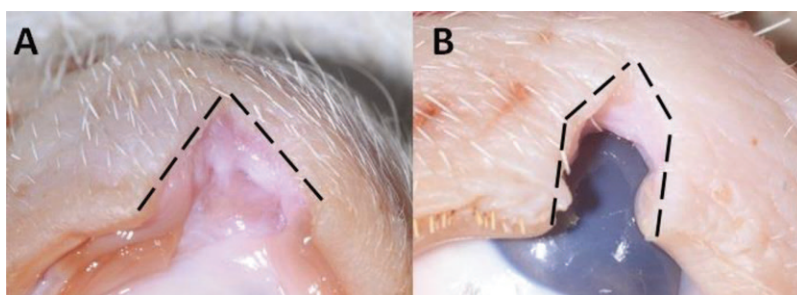


Fig. 9. Two different surgical approaches for removing a small eyelid mass. A, A full-thickness wedge resection is performed by using Stevens tenotomy scissors to cut a triangular wedge (black stippled lines) out of the eyelid. B, A full-thickness “house-resection” (four-sided resection) is performed by using Stevens tenotomy scissors to cut four sides out of the eyelid (black stippled lines). Both eyelid wounds are closed as described in the text with one or more simple interrupted subcutaneous mattress suture(s), and a figure-eight suture at the eyelid margin followed by simple interrupted sutures in the skin (see Fig. 10; the two surgical approaches in A and B are shown on a cadaver pig eye.)

The eyelid mass site should be prepared for surgery as described under “restraint and preparation of the patient” and an auriculopalpebral nerve block, a supraorbital nerve block, and a ring or line block should be used for local analgesia. Direct infiltration of the mass with anesthetic should be avoided given that this will distort tissue architecture, interfere with histopathological interpretation, and possibly cause spreading of tumor cells.¹³

Surgery Description

1. Removal of a small eyelid mass is performed by gripping tissue right next to the mass with a Bishop Harmon forceps using the left hand (if the surgeon is right handed) and removing the mass with Stevens tenotomy scissors using the right hand (Fig. 9).

2. The tissue is removed using either a wedge or a “house-shaped” pattern as illustrated in Fig. 9. The wedge resection is a simple V-shaped pattern that is full thickness. The mass is removed in one piece with an adequate margin of normal tissue attached (Fig. 9A). The “house” resection pattern is also full thickness. It involves making two perpendicular incisions from the eyelid margin on each side of the mass, then connecting the two perpendicular cuts with a small V-shaped wedge incision (Fig. 9B). The house resection is the preferred pattern for removal of eyelid masses in horses as it avoids removal of excessive normal eyelid tissue.¹²

3. An impression smear can be collected for cytology analysis to obtain preliminary information regarding tumor type and possible malignancy. Smear analysis of eyelid masses must be followed with histopathology to obtain an exact diagnosis and determine whether the excised tissue margins are free of pathology. The eyelid mass is placed in a container with a 10:1 ratio of formalin fluid to tissue mass for subsequent submission to a reference laboratory.

4. The surgical incision should be sutured in two layers. The subcutaneous layer is closed with one or more sutures of 3-0 to 4-0 Vicryl in a horizontal mattress pattern, and the tarsal margin is closed

with a single 4-0 nylon suture with a P3 reverse cutting needle suture that is placed in a figure-eight pattern (Fig. 10). The palpebral surface of the lid conjunctiva should not be penetrated, given that the suture material could abrade the cornea and cause ulceration. The number of mattress suture(s) required to appose the subcutaneous tissue depends on the size of the tissue removed, but mattress sutures should not be placed too close to the eyelid margin given that this will complicate placement of the final figure-eight suture that brings the eyelid margin into exact apposition.

The figure-eight suture is a very important suture for periocular surgeries given that it will result in proper apposition of eyelid margins, avoiding corneal trauma.¹² The figure-eight suture is illustrated in Fig. 10, and the legend describes the sequential steps to insert the suture and close the eyelid margin. The figure-eight suture assures exact apposition of the tarsal margin while directing the suture tags away from the ocular surface.

5. The skin incision is closed in a simple interrupted pattern, using 4-0 Nylon suture with a P3 needle. The long figure-eight suture ends are tucked under the knots of the simple interrupted skin sutures to direct the tags away from the eyelid margin and ensure that these suture ends DO NOT touch the cornea and cause corneal ulcerations (Fig. 10F).

Postoperative treatment: The horse should be treated with systemic nonsteroidal anti-inflammatory drugs (NSAIDs) for 3 to 7 days (e.g., flunixin meglumine 1.1 mg/kg q 12 h PO). Concurrent treatment with a topical triple antibiotic ophthalmic ointment^g applied three times a day to the eye and along the incision site until suture removal 10 to 14 days after surgery. Depending on aseptic conditions during the surgery, an oral antibiotic^h (e.g., trimethoprim sulfamethoxazole [TMS] 25 mg/kg q 12 h PO) may be prescribed for 5 to 7 days. A hard-cup hood can be used to protect the surgery site given that any rubbing of the area can

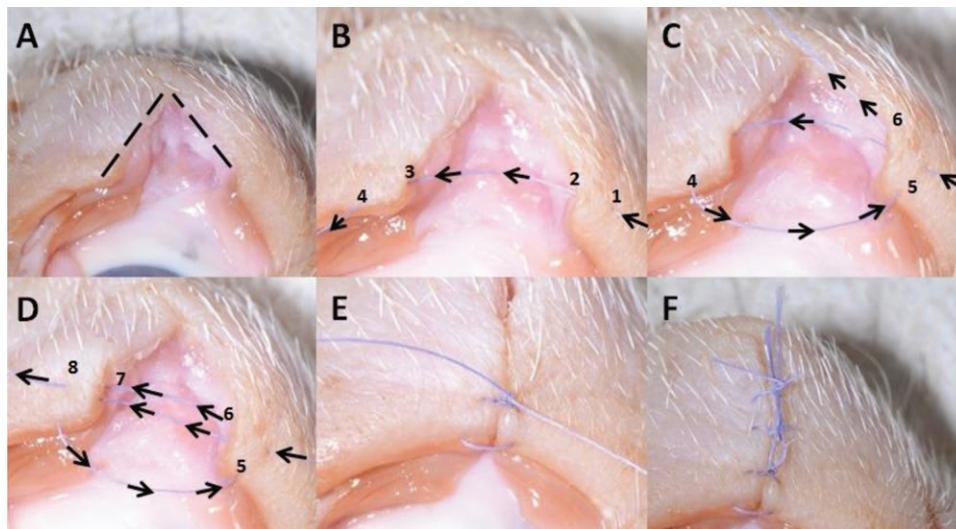


Fig. 10. The figure-eight suture. A, The figure-eight is used to appose eyelid margins in eyelid mass resection surgeries or in eyelid lacerations. This photo shows a wedge-shaped defect in the eyelid margin prior to closure. B, The first closure step involves penetration of the skin 3–4 mm away from the eyelid margin (1) with the suture exiting the adjacent subcutaneous tissue of the wound margin (2). The suture is then crossed over the incision to enter the subcutaneous tissue on the opposite side (3) and exit out at the eyelid margin. Great care is taken to assure that the needle exits along the plane of the Meibomian glands (4). C, The suture will then be crossed over the surgery incision again to enter the eyelid margin on the other side next to the Meibomian glands, (5) and exit the subcutaneous tissue a few millimeters away from the eyelid margin (6). D, The surgery incision is then crossed again. The suture enters the subcutaneous tissue, (7) and exits the skin at the same distance from the eyelid margin as the initial suture on the opposite side of the surgery incision (8). E, The tags of the figure-eight suture are tied together with a surgeon's knot, leaving the suture ends long. F, The skin incision is closed with simple interrupted sutures. The two tags of the figure-eight suture knot are tucked under the knots of the skin sutures to direct the tags away from the corneal surface. (The figure-eight surgery in Fig. 10 is being shown on a cadaver pig eye.)

cause suture rupture and incision breakdown. Sutures should be removed 10 to 14 days after surgery.

Repair of Eyelid Lacerations

Eyelid lacerations are a common trauma in equine practice. Repair of eyelid lacerations can be performed with the surgical techniques described for excision of an eyelid mass, but removal of eyelid tissue should be kept to a minimum. Surgical preparation and instillation of local nerve blocks are performed using the techniques described for eyelid masses. When the area is ready for surgery, the torn margins should be “freshened up” by prudent removal of any compromised tissue. However, the main “take-home message” for eyelid laceration surgery is DO NOT remove any healthy skin or eyelid tissue! It is critical for the surgeon to preserve an intact and functional eyelid as otherwise the cornea will become desiccated and severe keratitis with corneal ulceration and corneal perforation can occur (Fig. 1).¹⁴ A No. 15 blade or Stevens tenotomy scissors is used to debride the lacerated eyelid skin margins sparingly to eliminate potentially necrotic tissue and cause the lacerated margins to bleed. Apposing two skin surfaces that have a healthy blood supply sets the stage for rapid wound healing and good cosmesis. Suturing eyelid lacerations should always be attempted no matter how severe the extent of the laceration because even compro-

mised necrotic tissue can revitalize after surgery. When significant eyelid tissue is missing, blepharoplasty surgery by a skilled board certified veterinary ophthalmologist or veterinary surgeon using general anesthesia is recommended.

Surgery description: When the margins of the torn eyelid tissue have been “freshened up” the eyelid laceration will be sutured back together as described for excision of an eyelid mass. A small number of horizontal mattress sutures using 3-0 to 4-0 Vicryl should be placed in the subcutaneous tissue to appose the lacerated tissue. A figure-eight suture with 4-0 nylon with a P3 reverse cutting needle is placed in the eyelid margin to achieve a perfect union of the tarsal margin (Fig. 10). Simple interrupted sutures using 4-0 Nylon on a P3 needle are used to appose the skin. If the laceration is multiplanar, the repair proceeds along the various interrupted tissue planes to recreate the conformation of the original eyelid (Fig. 11).

Postoperative treatment: Postoperative treatment is the same as described for removal of small eyelid masses but oral antibiotic (e.g., TMS) therapy for 5 to 7 days is necessary in addition to a topical antibiotic^g and systemic NSAID (e.g., flunixin meglumine) therapy given that most eyelid lacerations are caused by trauma and are at high risk for infection. If an infection is already present at the site,



Fig. 11. Eyelid lacerations in horses should always be repaired and the torn eyelid margins are never cut off. A, Severe upper eyelid laceration in a horse. B, Same eyelid laceration in picture Fig. 11A after standing sedation and laceration repair. A figure-eight (white arrow) was placed in the eyelid margin to appose the lacerated area. The subcutaneous tissue was sutured with mattress sutures, and the skin was closed with simple interrupted sutures. (Photographs courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)

consider collecting a sample for culture and sensitivity testing prior to preparation of the surgical field.

Tacking Sutures for Entropion

Due to prematurity, dehydration, or sepsis, some foals are born with entropion of the lower eyelid, or may acquire the condition in the first few days of life. This type of entropion will resolve with time, hydration, and medical therapy and thus should not be treated with a permanent entropion surgery, given that removal of eyelid skin tissue would overcorrect the lid defect and cause an ectropion. Instead, entropion in neonates should be treated with temporary tacking sutures placed in the affected eyelid to assure that the haired skin on the inverted lid does not cause secondary damage to the cornea with subsequent ulceration.^{12,14} Tacking sutures can also be used in horses that present with “spastic entropion” from ocular pain secondary to corneal ulcers or an acute flare-up of equine recurrent uveitis. These horses benefit from temporary tacking sutures that prevent the hair of the inverted eyelid from abrading the cornea.

Surgery description: The horse should be well sedated. Foals may be placed in lateral recumbency to allow firm restraint of the head and safe access to the affected eyelid. If the foal has bilateral entropion it can be flipped over when the first eyelid is finished to permit suture placement in the fellow eye. If the foal is in lateral recumbency for the repair, the “down eye” should be protected with ophthalmic lubrication¹, and by resting the head on a towel or blanket to avoid iatrogenic damage from stall bedding. The surgery site should be cleaned as explained under “Restraint and preparation of the patient.” A local line block should be used in the eyelid area where the sutures are going to be placed. The author uses 4-0 Nylon suture with a P3 needle and places a number of vertical mattress

sutures as described in Fig. 12. The “take-home message” for this procedure is that it is better to overcorrect the entropion slightly given that the tacking suture will loosen up with time and brief exposure of the conjunctiva is acceptable.

Postoperative treatment: A hard-cup hood can be placed to avoid rubbing of the eye and disruption of the tacking sutures. The eye should be monitored 2 to 3 times a day to make sure that no complications are developing. Topical triple antibiotic⁵ (three times a day for 2 to 3 weeks) can be used on the sutures, but is not necessary if the foal/horse resists treatment.

Removal of the Third Eyelid

Removal of the third eyelid is another surgery that can be performed on a standing sedated horse. This procedure is most often performed to remove a tumor (e.g., SCC) but is occasionally indicated after nictitans trauma. Keratoconjunctivitis sicca (dry eye) is known to develop in small animals when the third eyelid is removed but this has not been reported to occur in horses, so it is fairly safe to remove the third eyelid without serious side effects.¹⁵

Surgery description: Restraint for third eyelid removal will require head support and heavy sedation. The procedure is best performed in stocks, although it can be done in a stall doorway or aisle. The surgery site should be cleaned as explained for the other procedures. An auriculopalpebral and a supraorbital block should be instilled. Local blocks in and around the nictitans are very important and should be placed in the area of the third eyelid base—through the skin surface as well as into the conjunctiva in the deep aspect of the medial canthus. The conjunctiva of the nictitans base and surface should be infiltrated with 1 to 2 mL of local anesthetic that is injected through a 25-gauge needle attached to a tuberculin syringe. The surface of the cornea and the inner and outer aspects of the

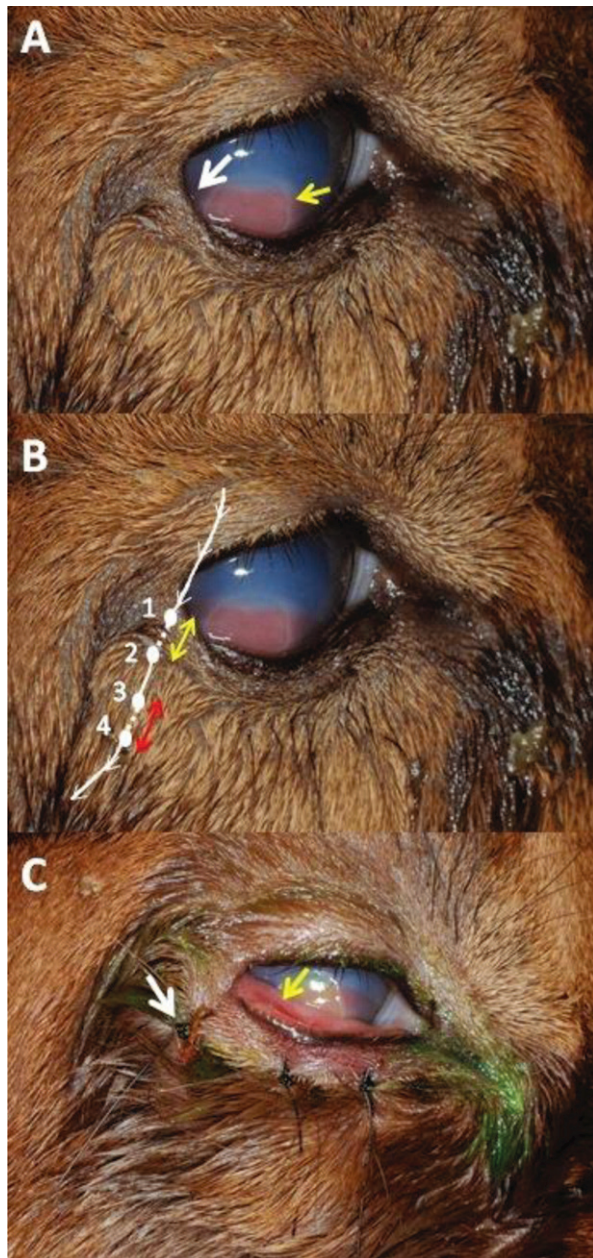


Fig. 12. A goat kid with entropion. A, The kid had developed a corneal ulceration with corneal edema and granulation tissue (yellow arrow) due to lower eyelid entropion (white arrow). B, Tacking sutures were placed as follows: 1 and 2) A suture bite that is 5–8 mm long is placed with the needle going through the skin and subcutaneous tissue (not full thickness) 2–4 mm from the eyelid margin (yellow double arrow). 3 and 4) The next suture bite of the initial vertical mattress suture is placed rostral to the first one (red double arrow), incorporating a similar amount of skin and subcutaneous tissue. The distance between the two vertical suture bites is dependent on the severity of the entropion. C, The tags to the two vertical suture bites are tied together with a surgeon's knot (white arrow). When the suture is tied the eyelid tissue that has been pierced by the suture bites should assume a wrinkled contour that results in eversion of the inverted tarsal margin (yellow arrow). The number of tacking sutures depends on how much of the eyelid has rolled into the cul-de-sac (severity of entropion). In most cases, three to four tacking sutures are sufficient to affect eversion of the tarsal margin.

third eyelid conjunctiva should be sprayed with approximately 1 mL of topical anesthetic (proparacaine 0.5% ophthalmic solution^j). The surgery site should be cleaned as described for the other procedures using dilute 2% to 5% betadine solution that is flushed onto the nictitans and corneal surface. It is also recommended to spray a few drops of topical phenylephrine 10% ophthalmic solution onto the surface of the nictitans to cause vasoconstriction and decrease bleeding.

When the surgery site has been cleaned and is ready for surgery the following steps are taken to excise the nictitans:

1. An Allis tissue forceps or a small towel clamp is placed in the third eyelid margin and the third eyelid is retracted from the medial canthus (Fig. 13).

2. A curved hemostat is placed at the base of the third eyelid well below the T-shaped cartilage that occupies the center of the third eyelid. The hemostat is held in place for 60 seconds to decrease bleeding. The hemostat is then removed and a curved Metzenbaum scissors are used to excise the nictitans base along the line where the hemostat constricted the vasculature. The hemostat is placed again on the next portion of the third eyelid base and held there for another 60 seconds, and the scissors are used to separate the next piece of third eyelid base from the palpebral conjunctiva. The process is repeated to complete the excision of the deepest portion of the nictitans base. The curved hemostat is then applied to the superior margin of the nictitans adjacent to the bulbar conjunctiva and similar hemostasis is applied to the upper margin of the structure, followed by sequential separation of the occluded tissue with curved Metzenbaum scissors until the third eyelid is removed in a single piece (Fig. 14).

3. The third eyelid should be submitted for histopathology if there is concern for neoplasia.

4. It is important to palpate the base of the third eyelid after the procedure to ensure that the T-shaped cartilage of the third eyelid has been removed completely, given that leftover cartilage can cause friction on the cornea, discomfort, and corneal ulceration (Fig. 15).

5. The conjunctiva and subcutaneous tissue in the deep aspect of the ventral-medial canthus fornix can be cryoablated in case of potential neoplasia.^{12,14} It is important to protect the cornea from the cryoablation to prevent corneal ulceration.^{14,15} This can be done by covering the portion of the cornea adjacent to the cryoablation site with a piece of Styrofoam cut out of a disposable coffee cup. Cryoablation can be performed with either a cryo-probe or liquid nitrogen in a spray bottle^{k,12}. The liquid nitrogen spray bottle will produce a noise that is irritating to the horse, so placing cotton balls in the ears and heavy sedation is advised for this procedure. Two-freeze-thaw cycles of 25 seconds per cycle at -80°C are recommended for each focus of cryoablation.



Fig. 13. An Allis tissue forceps (A) or a small towel clamp (B) is placed in the third eyelid margin and the third eyelid is retracted from the medial canthus (Photographs courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)

Postoperative treatment: Postoperative care is the same as for removal of small eyelid masses: 5 to 7 days of topical broad-spectrum ophthalmic antibiotic ointment application to the tear film three times a day⁶ and systemic NSAID administration one to two times per day for 3 to 7 days (e.g., flunixin meglumine). It is recommended that all horses that have undergone nictitans excision also should be treated with an oral antibiotic for 5 to 7 days (e.g., TMS), especially if the third eyelid is being removed due to trauma. Collection of samples for culture/sensitivity from the surgery site is recommended if there are concerns about a pre-existing infection.

Complications: One potential complication of third eyelid removal in horses is retrobulbar fat prolapse where adipose tissue residing deep in the orbit protrudes into the nasal canthal region after this area has been disturbed surgically. This complication can often be prevented if a continuous line of 6-0 Vicryl suture is placed in the medial deep conjunctival wound bed after the nictitans is excised.¹⁴ It is difficult, however, to place this continuous suture in a standing sedated horse. If the owner desires a surgical approach that minimizes this risk, nictitans removal should be performed by a veterinary ophthalmologist under general anesthesia. The risk of corneal ulceration is theoretically higher in horses that have undergone nictitans removal because the third eyelid is not present to



Fig. 14. A curved hemostat is placed at the base of the third eyelid (under the third eyelid cartilage) to decrease bleeding, after which the hemostat is removed and curved Metzenbaum scissors are used to separate the nictitans from the parent conjunctiva until the third eyelid can be excised in one piece (Photograph courtesy of Dr. Fausto Bellezzo, University of Minnesota.)



Fig. 15. It is important to palpate the base of the third eyelid after the procedure to ensure that the third eyelid cartilage has been removed completely, since any leftover cartilage can cause friction on the cornea with discomfort and corneal ulceration (Photograph courtesy of Dr. Ann Dwyer, Genesee Valley Equine Clinic, Rochester, NY.)

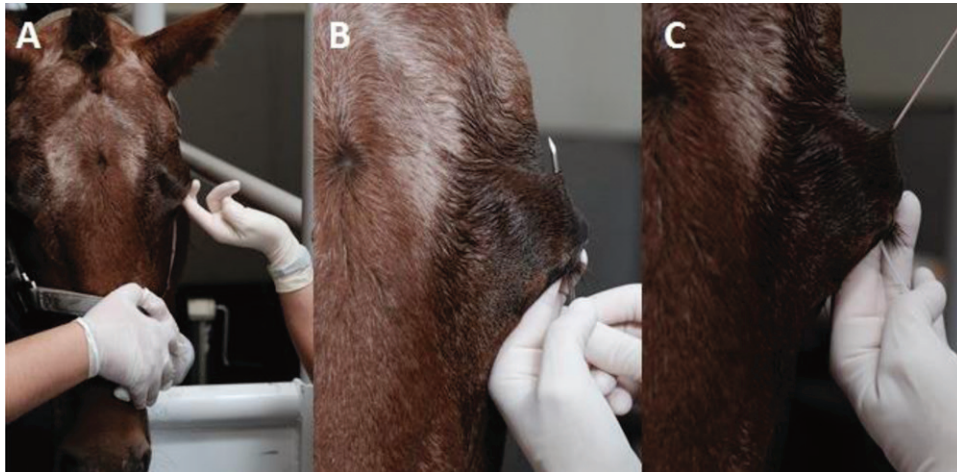


Fig. 16. Placement of a SPL system. A, A right-handed clinician places the left index finger under the eyelid that will receive the SPL system (a left-handed clinician would use the right index finger). B, The SPL-system trochar is placed along the left index finger and the finger/trochar is carefully inserted under the eyelid and deep into the conjunctival fornix (upper eyelid) or cul-de-sac of the nasal canthus (lower eyelid). The dominant hand is used to push the trochar into the conjunctiva, subcutaneous tissue and skin in a smooth, quick motion. C, When the SPL-trochar has pierced the skin, the rest of the tubing system is pulled through the eyelid until the SPL footplate is located in the conjunctival fornix. (Photographs courtesy of Dr. Christie Wards, University of Minnesota.)

protect the cornea, but ulcers are rarely diagnosed in these patients.

Placement of a SPL System

Horses frequently suffer painful corneal ulcers. Some corneal ulcers become infected or undergo severe collagenolysis. These cases require intense therapy that can involve topical ophthalmic medication administered 6 to 24 times a day with up to four to six different eye medications delivered at 5-minute treatment intervals. Such treatment must be administered through a SPL system. Placing a SPL system is an important skill for equine practitioners that treat ophthalmic diseases in their practices. A SPL system makes frequent treatment much easier for horse owners and will ensure good compliance for both high- and low-frequency treatment schedules. SPL systems come in kits that are available in 36- and 60-in. lengths¹; the 60-in. SPL system is advised given that this length of tubing accommodates large horses and can be cut shorter for smaller horses and foals.

The author recommends that horses that are treated with SPLs not have access to a pasture and preferably remain in a stall. Barn temperatures can fall well below 32°F in the winter in far-northern locations, permitting the liquid contents of the SPL line to freeze. The owner should be consulted about stabling options for any horse that is a candidate for SPL placement to assure that the housing conditions are optimal for SPL function.

Insertion of a SPL System

Placement of a SPL requires heavy sedation, appropriate restraint, and solid head support of the mandible so the horse's head remains still during the

insertion process. The author prefers to place SPL systems in the upper eyelid given that gravity will help the eye medication access the cornea. SPL systems that are placed in the lower eyelid have been demonstrated to be as effective as upper-eyelid SPL systems, and may be easier for some practitioners to place.^{3,16} Therefore, SPL systems can be placed in either eyelid according to practitioner preference unless there is some mitigating circumstance that requires placement in one lid or the other. The skin of the target eyelid is cleaned with 2% to 5% dilute betadine solution as previously described. The corneal surface and eyelid conjunctiva should be rinsed with dilute 2% to 5% betadine solution, and these surfaces are numbed with a spray of topical ophthalmic anesthetic (e.g., proparacaine 0.5% ophthalmic solution). An auriculopalpebral block is performed and the skin in the region where the SPL trochar will exit near the orbital rim is blocked by local infiltration of 2 mL of lidocaine.

Once the chosen eyelid and ocular surface has been prepped, the clinician puts on a pair of sterile gloves, after unfolding the sterile paper glove wrapper on a table located near the sedated horse. The contents of the SPL kit are placed on the sterile glove wrapper surface. The coiled SPL tubing is unwound and gathered up in loops so it can be held in one hand. The SPL tubing is either held by the clinician or supported by an assistant holding the tubing on the sterile wrapper. Insertion of the tubing is accomplished via the steps outlined in the legend accompanying the photographs in Fig. 16. If the horse does not stand still when the clinician approaches the eyelid with the insertion trochar, the SPL tubing should be returned to the sterile glove

paper and the levels of sedation, block, or topical anesthesia should be optimized.

After the trochar has been used to pull the tubing through the hole that has pierced the eyelid, special care is taken to assure that the footplate of the SPL is snug against the palpebral conjunctiva and that the angle of the footplate matches the angle of the palpebral conjunctiva.

Once the SPL tubing is placed, the clinician must verify that the tubing hole is deep in the fornix so the footplate cannot abrade the corneal surface. To assess placement the tubing near the exit site is pulled gently to see if the eyelid moves. If the eyelid moves there is a good chance that the SPL footplate has not been placed correctly and there is a high risk for the system to rub against the cornea and cause corneal ulcerations. If the footplate has not been correctly placed, the SPL system should be replaced with the trochar inserted deeper into the fornix adjacent to the orbital rim (Fig. 17A).

After the clinician is certain that the SPL footplate has been inserted correctly, the remainder of the SPL tubing must be secured to the face and mane as illustrated in Fig. 16. Securing the SPL tubing system is just as important as placing it correctly, given that a piece of dangling SPL tubing can catch on a stall obstacle and break, or develop a kink that will not allow medication to flow to the tear film.

The SPL tubing is anchored to the horse's face with simple interrupted sutures placed through butterfly tabs made of porous white tape that are fixed to the tubing. 2-0 Nylon suture on a straight cutting needle is used to place the simple interrupted sutures (Fig. 17B). The distal end of the tubing is threaded with a 20-gauge 1¼-in. catheter and then capped with a male catheter cap that will serve as an injection port. A half wooden tongue depressor is used as a splint. The tongue depressor is covered with white tape to attach the SPL port to the mane (Fig. 17C). This IV injection port should be evaluated daily for sterility.

A 1-mL syringe with an attached 25-gauge 5/8-in. needle is used to inject medication into the SPL system. Treatment is done by injecting 0.1 to 0.2 mL of medication into the injection port, then pushing the medication to the tear film by slowly injecting a 1–3 mL bolus of air, depending of the length of the SPL tubing. A 3-mL syringe attached to a 25-gauge 5/8-in. needle is used for the air injection. Saline or water is not recommended as a means of pushing the medication bolus to the tear film as liquids dilute the medication and decrease efficacy. It is recommended that medications be administered to the eye at a minimum of 5-minute intervals.

Maintenance of an SPL system: The SPL system should be checked daily if the horse is hospitalized. The underlying ophthalmic disease will dictate the frequency of veterinary examinations but the system should be checked by a veterinarian at least weekly. Suture integrity of the white tape tabs on

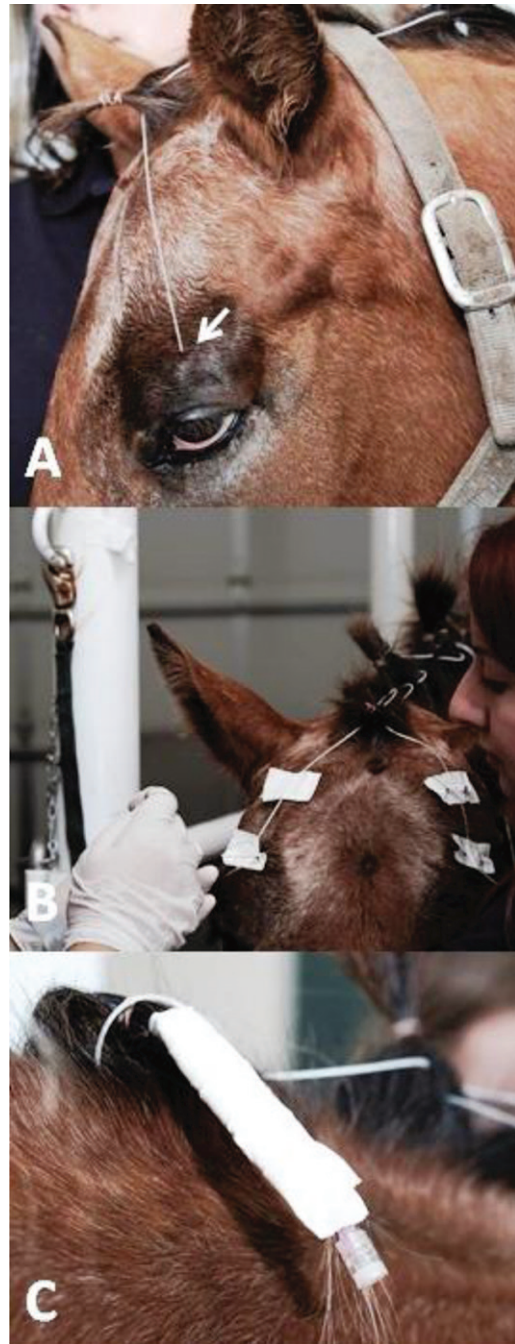


Fig. 17. Correct placement and securing of the SPL system is important. A, The SPL system should be placed in the conjunctival fornix (deepest part of the eyelid) and come out in the area of the orbital rim (white arrow). The eyelid should not move when slight tension is applied to the tubing adjacent to the exit hole. B, The SPL system should be anchored to the horse's face with white porous tape and sutures. Nylon 2-0 suture with a straight cutting needle is used to suture the porous tape tabs to the forehead of the horse. The SPL tubing is braided into the horse mane to prevent dangling SPL tubing. C, Half of a wooden tongue depressor is used as a splint to attach the SPL injection port to the mane. The tongue depressor is covered with white tape to protect silicone tubing. A 20-gauge 1¼-in. catheter and male catheter cap have been threaded into the end of the silicone tubing to facilitate treatment. (Photographs courtesy of Dr. Christie Wards, University of Minnesota.)

the forehead should be checked daily and repaired if they loosen or break. It is also beneficial to flush the SPL system with 3–5 mL of sterile saline periodically to ensure patency of the system and the absence of holes. The male catheter cap injection port should be changed regularly. If the tubing on the SPL system breaks or develops a hole, it can be splinted using a 20-gauge intravenous catheter. Details of the tubing repair process, as well as other tips for field maintenance of SPL systems can be found in a paper in a previous AAEP proceedings.¹⁷

Removal: When the SPL system is ready to be removed, the horse may need to be sedated and the conjunctiva and cornea should be numbed with local anesthetic (e.g., proparacaine 0.5% ophthalmic solution). An auriculopalpebral nerve block may be needed, but many horses allow removal without regional anesthesia. The SPL tubing is cut a few inches above the eyelid exit hole. A sterile glove is placed on the clinician's dominant hand. The index finger and thumb are inserted and the footplate is pulled away from the conjunctiva. The severed tubing is pulled retrograde through the eyelid skin and the remainder of the SPL system is then removed from the face and mane.²

Occasionally, when the SPL system has been in place for a long period of time the SPL-footplate is covered with conjunctiva. In this case, the SPL-footplate will have to be removed through the exit hole in the eyelid. The exit hole region should be cleaned with 2% to 5% betadine solution and the area is blocked with infiltration of the skin with lidocaine. A No. 15 blade is used to cut a small line that extends from the exit hole to 1 to 2 mm on each side of the SPL-tube. The SPL-footplate is loosened from the conjunctiva and subcutaneous tissue by gently pulling the attached tubing from one side to another until the footplate can be removed through the exit hole. This may take time, but it is important not to pull too fast, given that the tubing system can break and leave the SPL-footplate buried in the subcutaneous tissue, which will require opening the exit hole wider to locate the plate. The approach to remove the buried footplate must be performed through the skin as the space between the cornea and the palpebral conjunctiva is too narrow to permit removal from the conjunctival side.

Postprocedure treatment: The author recommends using topical triple ophthalmic antibiotic ointment^g three times a day for 3 days after removal of a SPL system, and administers oral NSAIDs (e.g., flunixin meglumine) for 2 days to address potential swelling and discomfort. A hard-cup hood is kept on for 3 to 5 days after removal of a SPL system to decrease risk of rubbing the face and eye.

Complications: In rare cases, cellulitis/blepharitis can occur after a SPL system is placed (Fig. 18). In these cases, the SPL system should be removed and the area should be hot/cold packed for a couple of days. Collection of samples for culture/sensitivity from the exit hole or infected site is recom-

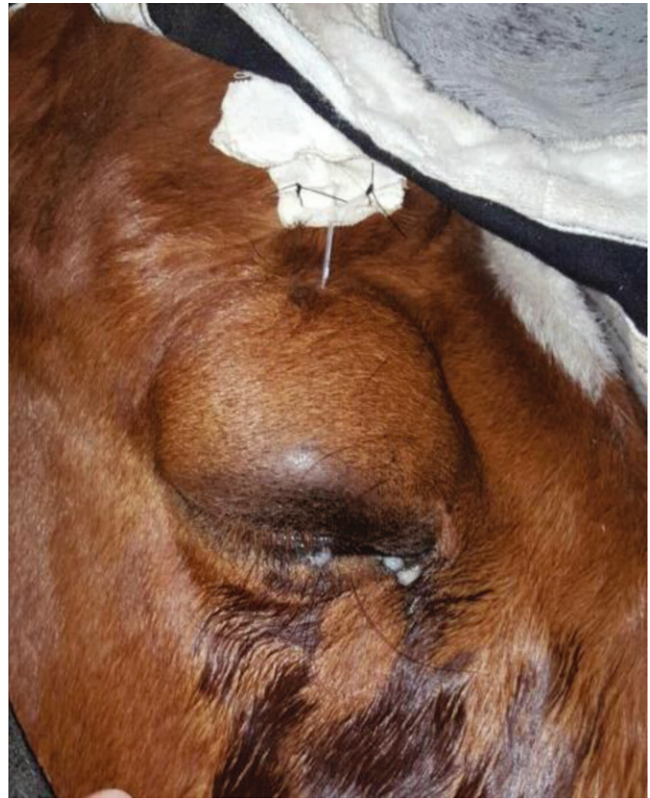


Fig. 18. A horse with periocular cellulitis and mucopurulent discharge caused by a SPL system in the upper eyelid. The SPL system was removed and replaced to the lower eyelid. The horse was started on oral TMS and a culture/sensitivity was taken from the mucopurulent discharge. The culture came back with positive growth of methicillin-resistant *Staphylococcus aureus* (MRSA). The cellulitis healed within 1 week after the SPL system was removed. MRSA was later isolated from noninfected skin areas of the horse. No new infection was seen in the lower eyelid SPL system. (Photograph courtesy of Dr. Kaitlin Mielnicki, University of Minnesota.)

mended if there are concerns about infection. The horse should be started on systemic antibiotic (e.g., TMS) for 5 to 7 days. Most eyelid cellulitis cases are sterile and will resolve within a couple of days after the SPL system has been removed. A different SPL system should be placed in the opposite eyelid (upper vs lower eyelid) and will not usually cause cellulitis/blepharitis in the new target eyelid.

6. Take-Home Message

Standing surgery of the periocular region in horses involves a set of clinical skills that are often needed by equine practitioners to treat common field conditions. Study of anatomy, instrumentation, and simple microsurgical techniques will enhance clinical outcomes. Preparation for surgery is important and involves sedation, patient restraint, head support, and prudent tissue handling. Practitioners that are interested in performing standing periocular surgeries should master the clinical skills that

are needed to perform common procedures such as removal of eyelid masses, repair of eyelid lacerations, removal of the nictitans, and the tacking procedure for entropion. Placement of a SPL treatment system is another important clinical technique commonly used by equine practitioners to aid treatment of corneal ulceration in horses.

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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^aDormosedan, Zoetis, Inc., Kalamazoo, MI 49007.

^bAcepromazine, VetOne, Boise, ID 83705.

^cTorbugesic, Zoetis, Inc., Kalamazoo, MI 49007.

^dHospira, Inc., Lake Forest, IL 60045.

^eOptivisor, Donegan Optical, Lenexa, KS 66219.

^fEthicon, Somerville, NJ 08876.

^gBacitracin, Neomycin, Polymixin B (NeoPolyBac), Bausch & Lomb, Rochester, NY 14609.

^hAmneal Pharmaceutical, Hauppauge, NY 11788.

ⁱLubriFresh PM, Major Pharmaceuticals, Livonia, MI 48150.

^jBausch & Lomb, Rochester, NY 14609.

^kVerruca-Freeze, Cryosurgery, Inc., Nashville, TN 37205.

^lSPL System, MILA International, Florence, KY 41042.

How to Obtain and Interpret Corneal Cytology Samples

Ann E. Dwyer, DVM

Corneal cytology is an essential diagnostic test for cases of ulcerative keratitis, and obtaining a corneal cytology sample is easily performed in the field. Microscopic evaluation of stained samples will demonstrate presence or absence of inflammation, infection, or noncellular elements. Interpretation of this evidence combined with the clinical examination and tests such as culture/sensitivity guides prudent therapy and rational management of a variety of ocular surface diseases. Author's address: Genesee Valley Equine Clinic, LLC, 925 Chili Scottsville Road, Scottsville, NY 14546-9751; e-mail: adwyer@rochester.rr.com. © 2017 AAEP.

1. Introduction

The equine cornea is the ovoid transparent portion of the outer tunic of the globe that serves as a “window” that admits light into the eye. The normal horse cornea is very thin, with a central depth of slightly less than 1 mm. The horizontal corneal diameter is a little less than 35 mm and the vertical height is slightly less than 25 mm. The precorneal tear film forms a boundary layer between the air and the outer epithelial cell layer. The epithelium, which makes up approximately 15% of the total corneal thickness, consists of 8–12 layers of nonkeratinized stratified squamous cells. A basement membrane below the epithelium forms the interface between the epithelium and the thickest layer of the cornea, the stroma. The stroma, which comprises over 80% of the corneal depth, is predominantly collagen fibrils, which are arranged in a geometrically precise lamellar extracellular matrix studded with a sparse, tiered net of keratocytes. Descemet's membrane is the basement membrane that is adjacent to the base of the stromal tissue. This

elastic membrane abuts with the deepest layer of the cornea, the endothelium, a very thin monolayer of cells that functions as the outer barrier of the anterior chamber. The endothelium provides an active osmotic gradient that nourishes the cornea, yet keeps the stroma relatively dehydrated and transparent.¹

Ulcerative disease of the cornea, which by definition means segmental loss of corneal epithelium that may or may not involve a deeper stromal defect, is very common in horses. Diagnosis of ulcerative disease involves application of fluorescein dye to the ocular surface. The green dye will stain areas of the hydrophilic stroma that are denuded of epithelium. In rare cases where the ulcer depth has penetrated the entire depth of the stroma down to Descemet's membrane, the bottom of the ulcer trough will lack stain uptake and appear as a dark ring outlined by dye staining the adjacent stroma.

Equine corneal ulcers are often complicated by infection with bacterial or fungal pathogens. Some ulcers become chronic due to the presence of foreign bodies. Others are compromised by the inflamma-

NOTES

tory reaction mounted by host polymorphonuclear cells that infiltrate the ocular surface. These inflammatory cells release proteases into the tear film that digest stromal collagen, causing the corneal tissue to swell and melt. Some ulcers fail to heal due to mineral deposition or failure of new epithelial cells to properly anchor to the basement membrane and underlying stroma. Such complications threaten corneal transparency and jeopardize vision.

Corneal ulcers are often accompanied by severe ocular pain, and are a frequent reason that veterinarians are summoned for emergency calls. Many ulcerative conditions advance rapidly and can progress to blinding sequelae. Accurate, rapid assessment of the status of the affected region of the ocular surface is a critical part of the diagnosis of corneal ulcers. Successful resolution of corneal ulcers requires targeted therapy that is specific for the underlying condition.

Obtaining a corneal cytology is a simple stall-side procedure that provides essential information needed to prescribe rational therapy. The materials needed for cytology sampling are inexpensive and readily available. Clinicians or technicians can readily learn to recognize corneal cytology profiles that suggest infection, inflammation, or other abnormal conditions. A rapid diagnosis of the microenvironment of the affected ocular surface leads to a targeted treatment plan that may be sight saving.^{2,3}

2. Materials and Methods

The following materials are required to obtain a corneal cytology sample in the field:

- 2% povidone iodine solution in a pour bottle (to clean periorbit)
- 4 × 4 gauze squares (to clean periorbit)
- Sedation (xylazine and/or detomidine hydrochloride)
- Small number of 3- and 1-mL syringes
- Small number of 25-gauge, 5/8-in. needles
- Local anesthetic (mepivacaine or lidocaine)
- Topical anesthetic (0.5% proparacaine or tetracaine)
- One pair of sterile gloves
- Sampling instrument: scalpel blade (size Nos. 10–15), kimura spatula, or cytobrush
- Two to four microscope slides with frosted ends
- Pencil to label slides
- Plastic slotted microscope box
- Sterile cotton-tipped wooden swabs (to complete corneal debridement after cytology sample is obtained)

These items can be stocked with other supplies in a designated ophthalmic tote box in the ambulatory vehicle.

Most practitioners use scalpel blades as a sampling tool for corneal cytology. Blade size Nos. 10, 11, 12, or 15 can be used, given that only the blunt



Fig. 1. Single scalpel blades can be autoclaved in sealed pouches to assure sterility for cytology sampling. Cytobrushes can also be used as sampling tools.

base of the blade is used. Individual blades should be placed in peel-away autoclave pouches and sterilized ahead of time to assure that the outer foil wrapper, which is used as a handle for the blade base and a cover for the sharp part of the blade, is sterile during sampling (Fig. 1). Some clinicians prefer Kimura spatulas as sampling instruments; individual spatulas should also be pre-sterilized in peel-away pouches.

Disposable cytobrushes that are sold in sterile paper packages can be used as sampling tools, but brushes may not generate sufficient surface pressure on the cornea to dislodge an adequate sample of cells for analysis. Most clinicians prefer using a metal tool for corneal sampling because it can be applied to a precise area of the cornea, and a blunt blade dislodges a generous sampling of material. However, the pressure generated by a metal instrument may risk damaging the cornea in globes with very deep or melting ulcers that are tectonically unstable. In these cases, sampling can be performed with a cytobrush or Dacron-tipped swab.

It should be noted that cotton-tipped wooden swabs are not appropriate tools for obtaining cytology samples. There are two reasons for this: 1) swab sampling tends to yield insufficient sample volume, and 2) cotton threads from the swab head inevitably end up on the slide, creating artifacts that confuse interpretation. However, five to ten sterile cotton-tipped wooden swabs are needed to debride the corneal lesion after the cytology sampling is completed. Peel-away autoclave pouches can be used to sterilize small numbers of swabs for this purpose.



Fig. 2. Materials for corneal cytology should be sent out on a clean table prior to sedation of the patient.

Preparation of the Examination Area

Field corneal cytology sampling is usually carried out in a barn aisle or stall doorway. The area should be clean, well lit, and wind free. Horses that require corneal cytology often need additional procedures such as subconjunctival injection, lesion debridement, or subpalpebral lavage system placement. Volume of sedation and time to complete all tests and procedures is minimized if the clinician takes a few minutes to stage the examination area and set up all needed supplies prior to any handling or sedation of the horse.

Items for corneal cytology should be laid out on one or two folding tables located close to the patient, along with any other materials needed for evaluation or treatment of the case. One or two 3-mL syringes designated for periocular nerve block(s) should be filled with local anesthetic and capped with a 25-gauge, 5/8-in. needle. Another syringe should be filled with 0.5–1.0 mL of topical anesthetic and capped with a 25-gauge needle that has had the needle stem broken off to expose the hub base (Fig. 2).

Two to four glass slides are taken out of the storage box and placed on the table. The frosted end of each slide is labeled with the patient name, owner name, date, and the eye being sampled (ocular sinister-OS-left eye or ocular dexter-OD-right eye). The inner surface of the open paper surgical glove wrapper provides a convenient sterile surface to place the sampling tool after it is removed from the autoclaved pouch.

The clinician should construct a table that will support the sedated horse's mandible on a solid surface at a height just above the point of the horse's shoulder. Materials such as stacked bales covered

with a blanket, oil drums, or recycling bins make excellent head supports. The ocular surface needs to be well lit during the sampling process; visualization will be aided if the clinician dons a headlamp or if an assistant provides supplemental ocular surface lighting with a flashlight or Finoff transilluminator.

Preparation of the Patient

Intravenous sedation is administered after "exam room staging" is complete. Choice of sedative depends on the temperament of the horse, the degree of ocular pain, and the length and invasive nature of the sequence of procedures that will be performed. Xylazine at a dose of 0.5–1.0 mg/kg is usually adequate for quiet horses that do not require additional globe manipulation. Detomidine hydrochloride^a at a dose of 0.02–0.04 mg/kg will be required for horses that are very painful, or for those who need a lavage system placed.

After sedation is administered, the horse is positioned so that the mandible rests on the head support that was prepared. The handler stands on the side opposite to the eye destined for sampling, holding a lead rope snapped to the halter. If the lesion of interest is located near the superior limbus, the handler is instructed to tip the horse's head away from the clinician when sampling starts; oculoves-tibular motion induced by the oblique head position will rotate the target area into optimum position for lesion access.

Gauze sponges soaked with 2% povidone iodine solution are used to clean the periorbital region. Upper eyelid akinesia is achieved by injecting 1.5–2 mL of local anesthetic with a 25-gauge, 5/8-in. needle over the palpebral branch of the auriculopalpebral nerve. This nerve can be accessed just lateral to the highest point of the caudal zygomatic arch or in the ventral curve of the rostral zygomatic arch just caudal to the bony process of the frontal bone. Regional analgesia is achieved by injecting 1 mL of local anesthetic with a 25-gauge, 5/8-in. needle subcutaneously over the frontal nerve as it emerges from the supraorbital foramen in the frontal bone superior and temporal to the nasal canthus.

Digital photography of the corneal surface should be performed prior to cytologic sampling to document the presenting condition. Imaging of the cornea after cytologic sampling may also be useful to document any surface disruption that follows lesion debridement.^{4,5}

Topical ophthalmic surface staining with sodium fluorescein dye is indicated to demonstrate the extent of ulcerative keratitis; this stain does not interfere with corneal cytology interpretation and can be performed prior to cytologic sampling (Fig. 3).

If corneal culture and sensitivity testing is indicated, it is performed prior to cytology sampling or surface stain administration. Ideally, culture should be performed prior to topical anesthesia, but uncooperative or very painful patients will require topical anesthetic application prior to culture. Culture of

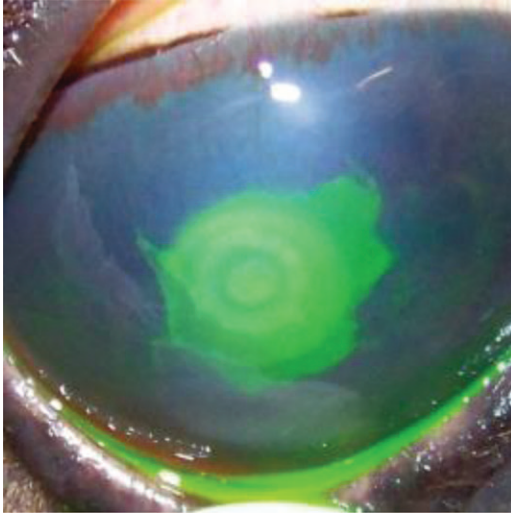


Fig. 3. Ulcerative keratitis cases should be evaluated by corneal cytology as well as culture. Cytology on this cornea showed mycotic keratitis.

the ocular surface can be performed with a sterile, moistened Dacron or calcium alginate-tipped swab or with the blunt end of a sterile scalpel blade. It is always best to assess ulcerative problems with a combination of culture and cytology, but clinicians should be aware that many cases of infectious keratitis fail to grow organisms on culture, either because of previous anti-infective therapy, or the presence of a fastidious pathogen that does not grow *in vitro*.

Topical anesthesia will be necessary for corneal cytology. The syringe that has been loaded with proparacaine or tetracaine and fitted with a 25-gauge needle hub is used to gently spray or drip a volume of 0.5 mL of anesthetic onto the corneal surface.

Steps of the Sampling Process

Corneal cytology and subsequent surface debridement are simple procedures that add no more than a few minutes to the ocular examination/treatment process.

The clinician dons gloves and opens and folds the foil wrapper of the sampling blade so as to expose the blade base but keep the sharp end of the blade covered. The thumb and index finger of the non-dominant hand are used to hold the horse's eyelids apart. The dominant hand is used to position the blade (or spatula edge) on the cornea at the edge of the lesion at a 45° angle. The metal edge is then scraped in a firm but gentle stroke across the disrupted corneal surface several times (Fig. 4). The blade edge is examined to assure that surface material is present. The blade is then positioned at a 45° angle to the middle of the glass slide and smeared in an even stroke to deposit material onto the slide surface in a monolayer. The sampling



Fig. 4. Corneal cytology sample is obtained with the blunt end of a sterile scalpel blade. The horse is sedated and has had an auriculopalpebral nerve block. The mandible is supported by stacked bales. Extra illumination of sample site was provided by a headlamp.

process is repeated a few times until material that looks like flakes of dandruff can be easily identified on the slide. The hand motion of dislodging and the sample from the corneal surface and depositing it onto the slide can be compared with that used when frosting a cake.

One to three additional slides are prepared in a similar manner. The clinician should choose a larger number of slides if cytologic analysis by a reference laboratory is anticipated in addition to in-house examination. The slides are stored in the plastic slotted box after each is examined to assure that a sufficient sample has been obtained. The slides will air dry in the box and can be stained at the end of the day (Fig. 5).

After the cytology sample is obtained, the corneal surface will need additional debridement to remove devitalized or disrupted epithelium. Five to ten sterile cotton-tipped wooden swabs are used for debridement. The swabs are used dry to permit the friction that is generated as the cotton tip is applied to the ocular surface to remove all loose epithelium. The swabs are firmly swept against the corneal surface in a motion that mimics writing on a chalkboard or using a pencil eraser. When a swab becomes wet with tears, it is replaced with a new dry swab. Debridement continues until probing with a dry swab proves that the border of the ulcerated lesion is tightly adherent to the underlying stroma.

Staining Corneal Cytology Slides

The following items are required to perform in-house cytology:

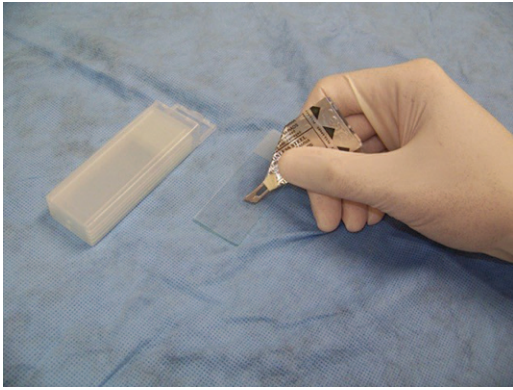


Fig. 5. Cytology sample is immediately transferred to a glass slide, checked to assure that particulate matter is visible on the slide. The slide is then labeled and placed in a plastic slotted box for transport.

- Diff-Quik stain set, with the three stain solutions held in Copley jars
- Gram stain kit, with the stain solutions held in small dropper bottles
- Faucet or rinse bottle
- Microscope with 10 \times , 40 \times , and 100 \times (oil immersion) objectives
- Small bottle of immersion oil with eye dropper or thin tip applicator
- Cell phone camera to capture microscope images of findings (optional)
- Template (digital or paper) to record findings

The main stain that is used for in-house, nonreference laboratory corneal cytology is the Diff-Quik stain process. The stains are stored in capped Copley jars or other containers with airtight screw tops, and the rapid staining process involves exposing the slide to three solutions in sequence. The first jar (Diff-Quik Solution 1) contains a light blue fixative reagent consisting of methanol and triaryl-methane dye; this solution fixes the material on the slide surface. The second jar (Diff-Quik Solution 2) is a red buffered solution containing xanthene dye and sodium azide. This jar stains cellular elements that are eosinophilic. The third jar (Diff-Quik Solution 3) is a dark blue buffered solution containing thiazine dye. This solution stains cellular elements that are basophilic. Table 1 outlines the staining characteristics of epithelial cells, blood cells, and other elements that may be found on corneal cytology samples (Fig. 6).

Diff-Quik stain was developed as a rapid “dip” commercial Romanovsky staining method. The stain provides good cytoplasmic detail and also stains many common microbiologic agents and extracellular elements. Opinions vary on the optimum staining process for corneal samples. Most clinicians use a method where the slide is dipped several times in fixative, holding the slide in the solution for 1 second per dip, then the short distal

edge of the slide is tapped on a paper towel to wick off excess stain solution. The process is then repeated with a number of dips in Diff-Quik Solution 2 (red), followed by tapping the slide on the paper towel, then by a number of brief 1-second dips in Diff-Quik Solution 3 (dark blue).

Many veterinarians are taught to perform “five dips” of the slide in each stain solution, with each dip lasting 1 second. The author prefers to dip the slide *six* times in the fixative, then *six* times in the red Diff-Quik Solution 2, and then *twelve* times in the dark blue Diff-Quik Solution 3. The longer immersion in the third jar yields superior cytologic detail and staining of structures like fungal hyphae. Some cytologists prefer an immersion technique where the slide is placed in the fixative for 3 minutes, then in the red solution for 1 minute, then in the dark blue solution for 3 minutes.⁶

The stained slide is then gently rinsed in a thin stream of water that is run from a faucet or rinsing bottle, and is propped vertically on the short edge to dry. Drying time may be facilitated by placing the slide in an incubator set at body temperature, or by propping the unstained rear surface of the slide in front of a mild stream of warm air such as that produced by a manicure machine designed to dry freshly applied fingernail polish.

Microscopic Examination

Once the slide is dry it is examined under the microscope. All areas that harbor stained material should be examined methodically. The slide is first inspected under low (10 \times) magnification to assess the pattern of material that is stained and to look for large foreign bodies. Then the slide is scanned from one end to the other under “high dry” (40 \times) magnification. Finally, the slide is examined under the high-power (100 \times) lens with a drop of oil placed over the stained material that is in contact with the lens surface. The examiner will take the longest time with the latter lens given that high magnification is needed to visualize cellular detail and microorganisms. It may be necessary to flip back and forth between low power and oil immersion to be sure that all relevant areas on the slide are inspected. Usually the slide will contain “rafts” of multilayered sections of corneal epithelium as well as individual or small groups of cells spread out in a monolayer. The small clusters of cells usually yield the most diagnostic information.

The task of examining corneal cytology samples is greatly simplified if the examiner remembers that a normal sample from the corneal surface should contain only squamous epithelial cells. These cells resemble fried eggs and may be seen in mosaic sheets or as small groups of cells on the slide. Superficial epithelial cells are flattened whereas basal cells tend to be cylindrical shapes. The cytoplasm of corneal epithelial cells stains light to medium blue in color. Nuclei are round to oval, basophilic, and centrally

Table 1. Elements Commonly Present in Corneal Cytology Samples

Structure	Diff-Quik Staining Features	Comments
Corneal epithelial cells	Round blue nucleus, light blue to violet cytoplasm	Much larger than inflammatory cells. Appear similar to fried eggs. Upper layers flattened, lower layers cylindrical.
Cytokeratin strands	Blue to violet strands	Very long, thin, strands of DNA from ruptured cells, may be confused with hyphae but do not branch or have parallel walls or septa. Create tangles that trap other elements on the slide.
Neutrophils	Segmented blue nucleus, pink cytoplasm, violet granules	Non-degenerate PMNs: crisp nuclear segments connected by threads.
Eosinophils	Violet nucleus, large round red cytoplasmic granules	Degenerate PMNs: fatter lobes, fewer threads linking lobes.
Monocytes	Violet nucleus, light blue cytoplasm	Look like raspberries. ± free extracellular eosinophilic granules.
Red blood cells	Pink/yellowish red cytoplasm, no nucleus	Violet nucleus, light blue cytoplasm. ± phagocytosed elements.
Bacteria	Blue to brown dots or specks	Smaller than inflammatory cells. Expected if vascularized lesion is disturbed.
Fungal hyphae	Walls and septa stain blue to violet, may show “negative staining” of outer wall outline and/or lumen	Cocci, rod or needle shape, may be found in chains, clusters, or other patterns. Can be intracellular or extracellular. If uniform and plentiful, likely significant.
Melanin granules	Brown, blue-black, or greenish in color, similar to small bacteria	Look for septate hyphae with parallel walls and branching patterns. May see spores or budding elements. Hyphae are <i>always</i> significant findings.
Stain precipitate granules	Dark blue in color, similar to small bacteria	Can be confused with small cocci bacteria; cluster in a pattern within cells. Stands out in thick rafts of cells. Will only be present if the sampled lesion was pigmented.
Intracellular drug inclusions	Light blue large oval structures within cytoplasm of squamous cells	Can be confused with small cocci bacteria. Looks like a lattice sitting on top of groups of cells, or in small beehive-shaped patches.
Calcium crystals	Blue color, variable in intensity	Sometimes occur when horses have received ointment therapy; small spherical packets of petroleum base are found within cells.
Vegetative foreign bodies	May or may not take up blue stain	Geometric extracellular crystalline shapes, usually smaller than epithelial cells. Look for typical plant microstructures like honeycomb or tubular elements or bristles.

Table 2. Tips for Ocular Cytology

- Use sedation, head support, and local anesthesia to assure patient cooperation
- After sampling, assure that particulate material can be seen on the slides
- Obtain extra slides for additional staining or submission to reference laboratory
- Change or filter stain solutions often
- Methodically evaluate all material on stained slide at 10×, 40×, and 100× (oil immersion)
- Use a system to record evidence of inflammation, infection, or noncellular elements
- Use a cell phone camera to record significant findings for the medical record

located. Any finding other than rafts or small groups of corneal epithelial cells is worth noting.

If bacteria are found on the slide, and are judged to be significant (abundant, and uniform, whether extracellular or intracellular), a separate slide should undergo standard gram staining. The record should then note whether the bacteria assumed a Gram positive (blue to purple) or Gram negative (red to pink) stain profile. It should be noted that interpretation of a sample of corneal cytology that has been Gram stained may be challenging, unless bacteria are very abundant and obvious.

The examiner records the findings of the cytology examination on a digital or paper medical record. It is helpful to prepare a template that has a checklist of common findings to assure that all pertinent detail is included. Elements of the record should include notation of the types of cells that are present, whether any microorganisms or foreign bodies are observed, and the staining pattern and shape of

Fig. 7. A paper or digital template record that uses a checkoff format for common elements seen on cytology examination is a useful system to record findings.

any abnormal organisms or structures. Artifacts such as stain precipitate or melanin granules should be noted (Fig. 7).

3. Results

The most common reason that corneal cytology is performed in horses is to assess ulcerative keratitis. Interpretation is guided by considering three simple questions:

1. *Is there an inflammatory infiltrate (presence of neutrophils, eosinophils, or monocytes)?*
2. *Are infectious elements (bacteria or fungi) present? If bacteria are seen, are they intracellular or extracellular, rods or cocci?*
3. *Are any foreign bodies (vegetative material, mineralized crystals, other object) present?*

The following descriptions outline ten profiles that are commonly seen in cytology samples taken from ulcerative lesions:

1. *Corneal epithelial cells with normal nuclei. Slide shows no inflammatory infiltrate, no microorganisms, and no foreign bodies: Cytology suggests a noninfected ulcer that lacks inflammation. If the lesion is chronic, it may be an indolent ulcer. Indolent ulcers often require debridement with a diamond burr instrument; a noninfectious cytology profile provides evidence that this kind of debridement is a safe therapeutic choice⁷ (Fig. 8).*

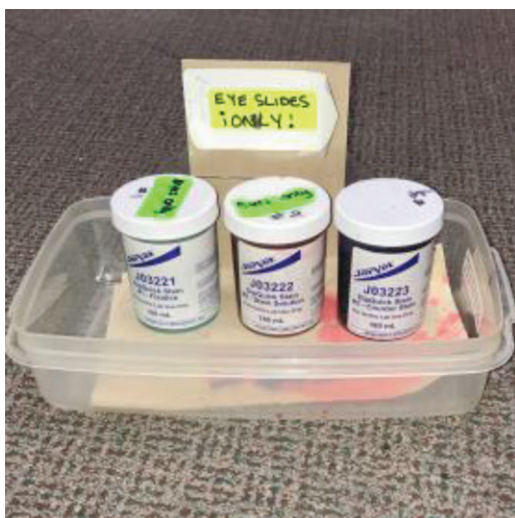


Fig. 6. Diff-Quik stain kit reserved for ocular cytology. The stains are stored in jars with screw caps. Stain No. 2 and Stain No. 3 solutions should be changed frequently and/or filtered through filter paper to avoid stain precipitate artifacts.

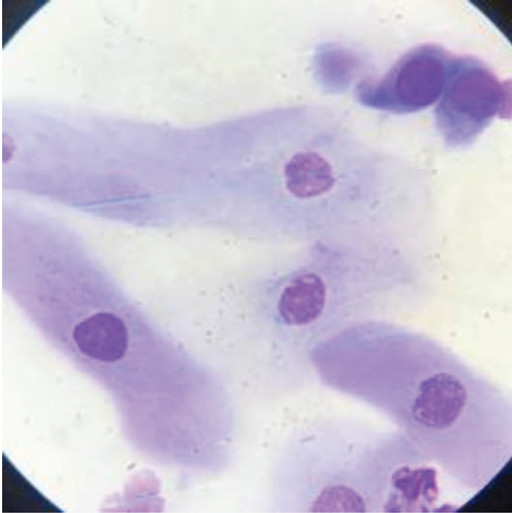


Fig. 8. Normal corneal epithelial cells are large cells with round central nuclei that stain blue to violet with Diff-Quik. Cells from the upper layers are flat whereas those from the lower layers are cylindrical. The round dots on this photo are artifacts from microscope lens debris (Diff Quik stain, 100 \times).

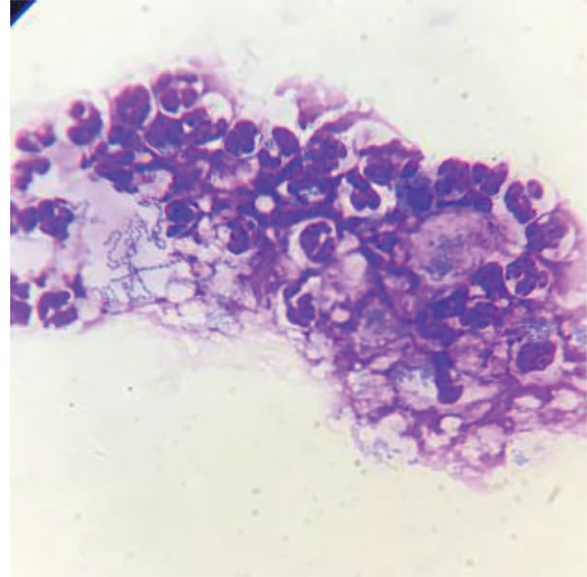


Fig. 9. Large numbers of neutrophils in this corneal cytology sample indicate an inflammatory infiltrate. Chains of extracellular cocci are present (Diff Quik stain, 100 \times).

2. *Corneal epithelial cells with normal nuclei. Slide shows large numbers of neutrophils that may show some degenerate characteristics:* Cytology demonstrates an inflammatory infiltrate that is at risk for collagenolysis (melting). This profile provides rationale for frequent topical therapy with one or more anticollagenase products (serum, ethylenediaminetetraacetic acid (EDTA), or acetylcysteine), and should prompt an investigation into a possible infectious etiology⁸ (Fig. 9).
3. *Corneal epithelial cells with normal nuclei. Slide shows numerous eosinophils along with a neutrophil infiltrate. Numerous bright pink granules are present on "empty" parts of the slide.* Cytology confirms a diagnosis of eosinophilic keratitis, a specific inflammatory condition that requires aggressive treatment. This profile provides a rationale for the use of systemic steroids and antihistamines in addition to topical diamond burr debridement of the lesion region, and appropriate topical anti-infectives⁹ (Fig. 10, A and B).
4. *Corneal epithelial cells with intracellular bacteria. The bacteria are uniform in shape and staining characteristics.* This profile is evidence of an infectious etiology. The shape and staining profile of the bacteria will suggest therapeutic agents that are logical choices pending the results of culture and sensitivity: Gram-positive infections may respond well to topical drugs such as cefazolin, chloramphenicol, or fluoroquinolones, whereas Gram-negative infections may respond well to topical aminoglycosides or fluoroquinolones. Bacteria may be found within the cytoplasm of epithelial cells or neutrophils¹⁰ (Fig. 11).
5. *Corneal epithelial cells with normal nuclei. A uniform population of extracellular bacteria are present in large numbers and neutrophils are abundant.* This profile is strongly suggestive of an infectious etiology (Fig. 12).
6. *Corneal epithelial cells with normal nuclei. Occasional areas with extracellular bacteria; mix of shapes and staining pattern.* This profile is less suggestive of an infectious etiology, but topical therapy should still include anti-infectives and an anticollagenase product. Sequential sampling may be needed to reassess.
7. *Corneal epithelial cells with normal nuclei. Fungal hyphae are present and can be found in both the thicker rafts of epithelium and amidst the small groups of cells in thinner monolayers.* This profile is absolute proof of mycotic keratitis, a very serious condition that requires aggressive, expensive therapy. The cytology confirms the need for antifungal agents as well as a topical anticollagenase product¹¹ (Fig. 13).
8. *Corneal epithelial cells with normal nuclei; multiple large pale blue ovoid structures in the cytoplasm of some cells.* If the horse has been on topical ointment therapy and the ulcer is not healing in a timely fashion, this profile suggests that the epithelial cells have taken up globules of the oily petroleum base material. Switching therapy from topical ointments to solutions may be beneficial.

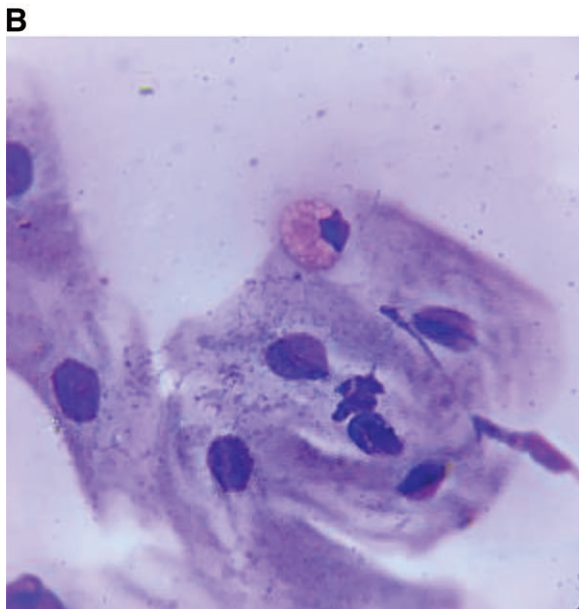
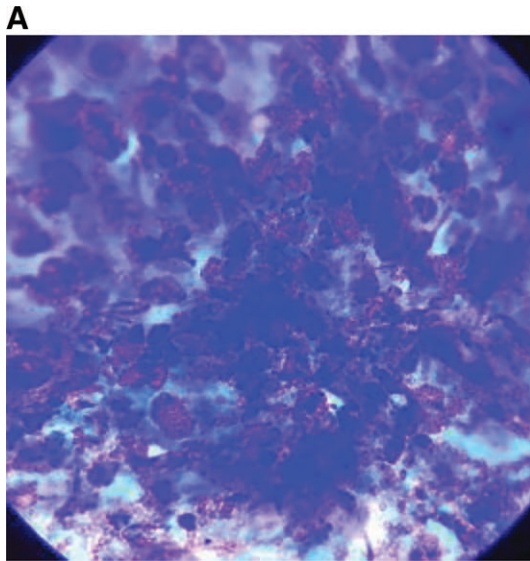


Fig. 10. A, Abundant numbers of eosinophils as well as individual granules are present within this raft of corneal epithelium, confirming a diagnosis of eosinophilic keratitis (Diff Quik stain, 100×). B, Individual eosinophils in “empty” areas of a sample also confirm a diagnosis of eosinophilic keratitis. The eosinophil, which is packed with large pink refractile granules, is adjacent to a cluster of epithelial cells packed with intracellular bacteria (Diff-Quik stain, 100×).

9. *Corneal epithelial cells with normal nuclei. Areas between rafts of cells show blue flat crystals that are rhomboid or rectangular shape. Crystals are usually smaller than an individual epithelial cell. This profile is usually proof of calcific keratopathy in the equine species. The clinician usually will have noted a gritty sensation when performing the cytology sampling and the blade base may have made a scratchy noise when opaque areas of*

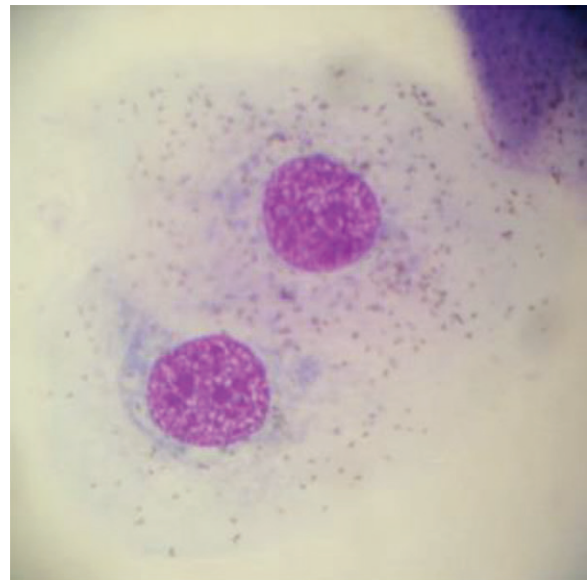


Fig. 11. Corneal epithelial cells packed with intracellular rod-shaped bacteria (Diff Quik stain, 100×).

the cornea were scraped. Confirmation of the diagnosis with cytology provides solid rationale for diamond burr debridement to burr away any remaining mineral, as well as follow-up chelation therapy with 1–4% EDTA¹² (Fig. 14).

10. *Presence of vegetative foreign body embedded in a raft of corneal epithelial cells. This finding may present proof that the cytologic debridement process has effected a cure by removing the offending agent. If the lesion*

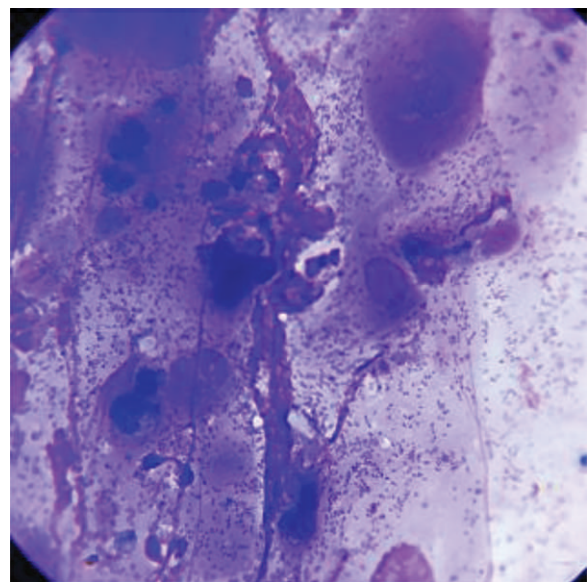


Fig. 12. Corneal cytology sample showing large numbers of extracellular cocci as well as cytokeratin strands, neutrophils, and epithelial cells (Diff quik stain, 100×).

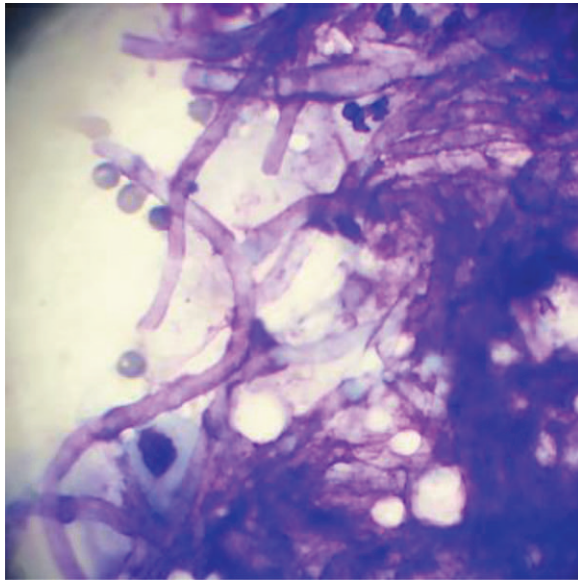


Fig. 13. Fungal hyphae and spores confirm a diagnosis of mycotic keratitis. Fungal elements branch and hyphae are septate with parallel walls. Degenerate neutrophils and epithelial cell debris are present (Diff Quik stain, 100 \times).

does not heal, it provides evidence to support further debridement to remove additional embedded material (Fig. 15).

Corneal epithelial cells that are pleomorphic (variable in size) and show anisokaryosis (variable-size nuclei) as well as a variable number of nucleoli, variable staining, and/or a varying ratio of nucleus to cytoplasm are suggestive of neoplasia. Corneal neoplasia is relatively rare in the horse, but suspi-

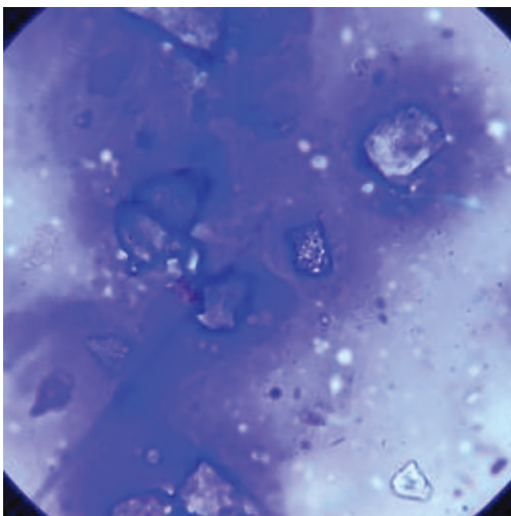


Fig. 14. Geometric shapes representing crystals of hydroxyapatite are present. When this sample was taken a "gritty" feeling accompanied blade debridement. Cytology confirms a diagnosis of calcific keratopathy (Diff Quik, 100 \times).

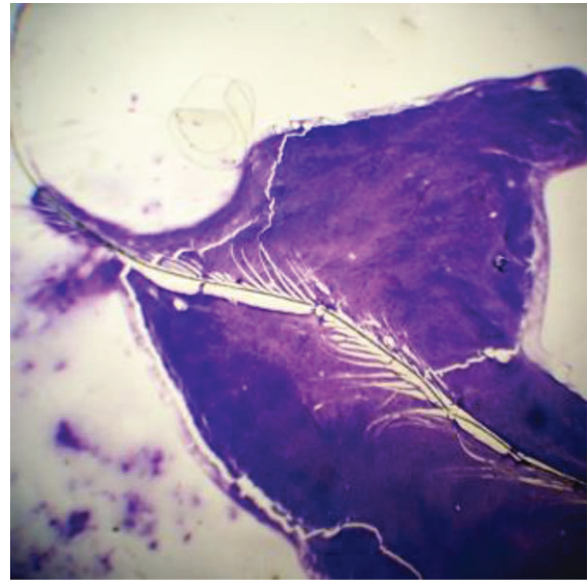


Fig. 15. A plant bristle is embedded within a raft of corneal epithelium, confirming a diagnosis of burdock bristle keratopathy (Diff Quik, 10 \times).

cion of neoplasia is another reason that cytology may be performed. Interpretation of potentially neoplastic tissue is beyond the scope of this review; clinicians are urged to send such samples to reference laboratories.

4. Discussion

As with any clinical pathology procedure, inadequate technique or the presence of certain artifacts or pathologic findings may hamper interpretation of corneal cytology. The most common problem is **insufficient sample of cells on the slide**. Inexperienced clinicians may be timid about applying a blunt metal blade to the corneal surface, fearing that excessive force will cause damage. Some ulcerative lesions exfoliate cellular material during scraping that is difficult to "trap" on the blade surface. In either case the resultant cytology slides may not contain a sample of sufficient quality.

Training in effective corneal scraping methods can be accomplished by practicing cytology collection on cadaver eyes. To do this, the sharp edge of a No. 15 scalpel blade is used to create a small ulcer on the normal intact epithelium of the cadaver cornea. The operator will note that the epithelium on the corneal surface is tough, requiring sharp dissection for disruption. A practice cytology sample can then be taken from the iatrogenic ulcer bed. The scalpel blade is flipped in the foil wrapper and the blunt edge is scraped along the ulcer margins to prepare several slides as described. The operator can then stain the slides to compare the amount of material that was grossly visible on the slide with the amount of stained material that is evident through the microscope. This exercise will help the clinician gain

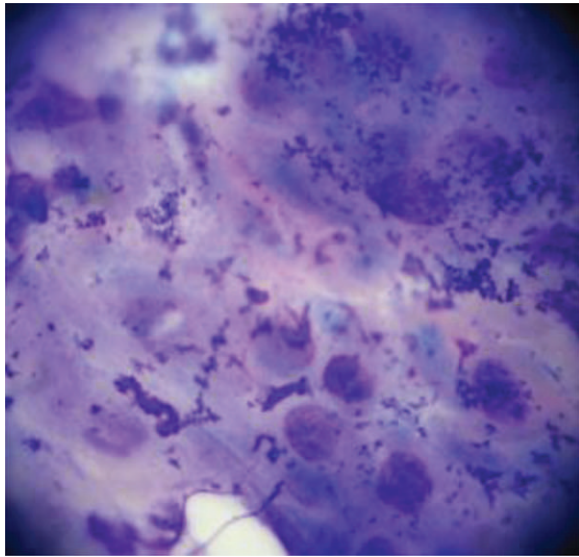


Fig. 16. Granular stain precipitate in cytology sample. The precipitate tends to form stellate clumps. Individual granules may be confused with coccoid bacteria. Stain solutions should be changed and filtered regularly to avoid this confusing artifact (Diff Quik, 100 \times).

familiarity and comfort with the amount of pressure required at the ulcer edge to dislodge and trap particulate material resembling flakes of dandruff.

Another issue that can confound interpretation is the presence of basophilic **Diff-Quik stain precipitate** that has adhered to rafts of cells or to “empty” portions of the slide. Solution 3 (blue) Diff-Quik stain will form precipitates in solution if it is old or if the container has been used to stain a lot of slides, and these tiny clumps of material will adhere to cells on the stained slides. The small dark blue particles are very hard to distinguish from bacterial cocci; thus, the presence of stain precipitate on a slide can produce a false-positive diagnosis of bacterial keratitis (Fig. 16). Two quality-control practices will help prevent this issue: frequent changing of the stain solution in the staining jars, and periodic filtration of the two stain solutions through filter paper. Laboratories that do a lot of cytology may keep a separate set of stain jars reserved just for ocular sample staining. The solutions should be changed at weekly to monthly intervals, depending on the frequency of use. At each change date, the coplin jars should be cleaned with soapy water, dried thoroughly, and labeled with the date. A short neck funnel lined with 110 mm filter paper folded into a cone can be used as a straining device to remove particles that accumulate between solution change dates.

A third issue that affects interpretation of certain cytology samples is the presence of **melanin granules** within the corneal epithelial cells. Like stain precipitate, the small granules can easily be confused with bacterial cocci. However, examination

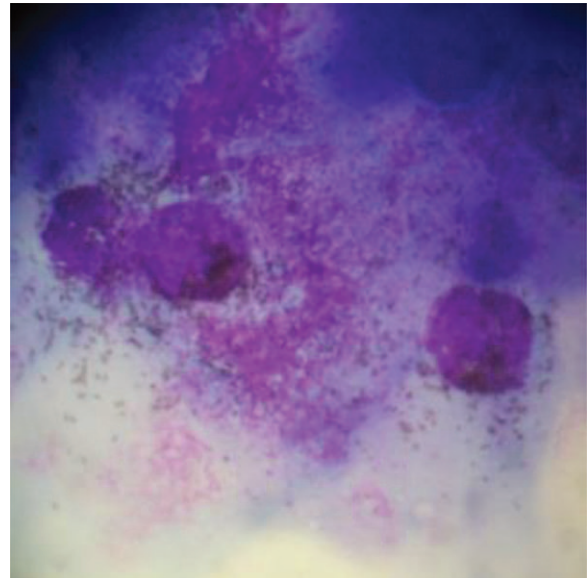


Fig. 17. Melanin granules are present on this cytology sample, taken from a lesion near the limbus. The granules stain greenish black to brown and form clusters that may overlie the epithelial cell nuclei. They are easily confused with bacteria (Diff Quik, 100 \times).

of the patient prior to sampling should prepare the operator for this finding. The two types of cases where this artifact may occur are in samples that are taken on or very near the limbus (where melanin is a natural presence in and around the limbal epithelial cells) or in samples that have pigment infiltrate in the normally transparent region of the perilimbal or axial cornea. There is no way to avoid melanin granules in such cases, but the pre-sampling examination should anticipate this finding, and the slides should be interpreted accordingly. Melanin granules demonstrate a golden-brown or greenish hue, where bacteria usually stain dark blue with Diff-Quik (Fig. 17). The presence of an inflammatory response is suggestive of bacterial involvement. Still, it may be difficult to distinguish the difference between melanin granules and coccoid bacteria.

A fourth issue that is a common source of confusion is the presence of **cytokeratin cellular debris**, cell fragments representing strands of nuclear chromatin. This finding is common in cases of infectious keratitis or keratomalacia; it follows widespread cellular rupture. The chromatin from the dead cells spins out into long thin tangles of nuclear material. The basophilic cytokeratin strands, which can be a very dominant feature on the slide in longstanding cases, form nets that trap cellular material. The strands, which are essentially tangles of DNA, are often confused with fungal hyphae. It may be necessary to examine multiple regions of the slide to decide if basophilic linear strands are cytokeratin or hyphae. Cytokeratin looks more like

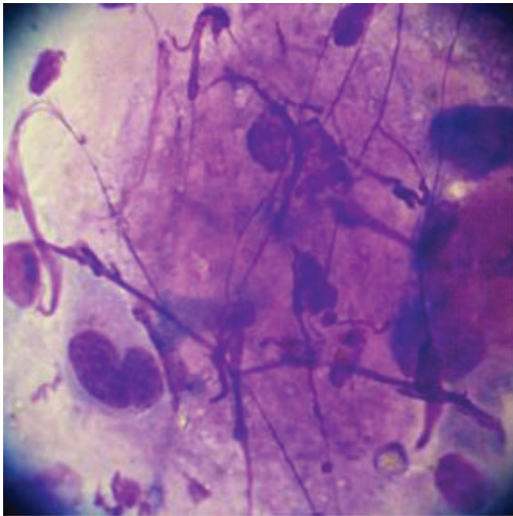


Fig. 18. Cytokeratin strands representing cytoplasmic contents that have been spun out from the nuclei of ruptured corneal epithelial cells. Commonly seen in samples of chronic ulcerative keratitis. Threadlike character can be confused with fungal hyphae, but cytokeratin elements lack parallel walls, septate hyphae, and do not exhibit negative staining (Diff Quik, 100 \times).

long cotton threads, or strands of cotton candy (Fig. 18). Fungal hyphae will show the hallmark characteristics of parallel walls, septate hyphae, and branching elements (Fig. 19).

Clinicians and technicians can become accurate assessors of corneal cytology if they keep the aforementioned information about artifacts and elements

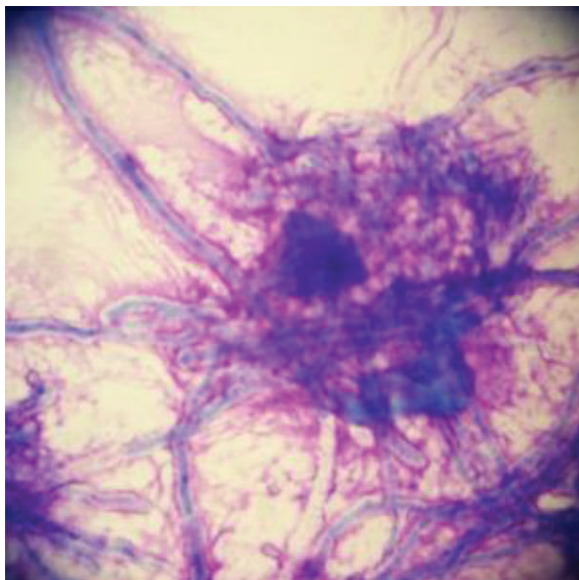


Fig. 19. Mycotic keratitis cytology. Basophilic elements demonstrate the parallel walls, and branching, septate character typical of fungal hyphae. Negative staining pattern is apparent. Cytokeratin debris is evident as violet filamentous debris around the hyphae (Diff Quik, 100 \times).

that can mimic infectious agents in mind. As a rule, corneal cytology is indicated in all but the most superficial, acute ulcers. Corneal cytology is especially indicated in chronic cases where there is an opaque region that represents an infiltrate associated with the ulcer. Serious cases of ulcerative keratitis often require weeks to months of therapy, and sequential cytologic sampling may be needed. There are no hard and fast rules of ulcer management/debridement frequency, but most clinicians wait approximately 1 week to decide whether additional debridement and/or cytology is necessary, unless the ulcer is deteriorating rapidly. Cytology is also indicated if a clinician decides they need to debride an area that is not ulcerated, such as a vascularized region associated with chronic ocular discomfort.

There are a few instances when corneal cytology with the blade technique is ill advised. Ulcers with severe, progressive keratomalacia are best assessed by rolling a cytobrush over the malacic tissue, or by making an impression smear by pressing the center of a slide onto the melting cornea. Similarly, it is not prudent to perform blade sampling on a desmetocele or extremely deep ulcer that has the potential to rupture.

As mentioned previously, interpretation of neoplastic cytology samples is beyond the skillset of most clinicians. Samples suspicious for neoplasia are best sent to clinical pathology reference laboratories. However, the clinician can make extra slides when debriding such cases, stain them in-house, and compare the observations they make with those of the clinical pathology report. This practice educates the clinician and provides a baseline for subsequent progress exams. In the same vein, clinicians who do not have a lot of experience with corneal cytology of nonneoplastic conditions will gain confidence in their interpretative skills if they make multiple slides of the first several cases they debride, and send one set of slides to a reference laboratory and analyze the second set themselves.

Many clinicians take photographs of interesting cytology findings through the microscope. Modern cell phones contain tiny camera lenses that capture excellent images through the ocular lens of the microscope; good results can be obtained with practice (Fig. 20). Cytology images can be inserted into the medical record, or shared with colleagues for consultation purposes. Simple and practical techniques for photographing microscopic images using cell phones or digital cameras have been described.^{4,5}

Collection and interpretation of corneal cytology samples to evaluate ulcerative keratopathy is simple and straightforward. It is easy for clinicians and technicians to attain skills in reading slides stained with Diff-Quik stain. Analysis of most common problems involves assessing the ocular surface sample to look for infection, inflammatory response, and/or the presence of extracellular elements like mineral or foreign bodies. Same-day analysis of cytology samples from horses suffering



Fig. 20. The tiny lens of modern cell phone cameras easily captures excellent digital images of cytology samples. Most of the images in this paper were taken with an Apple iPhone camera through the microscope shown.

severe ulcerative disease promotes selection of rational therapy that may be sight saving and guides proper management of cases that are chronic or nonresponsive.

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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How to Select Appropriate Treatment for Corneal Ulcers

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1. Introduction

The equine cornea is prone to ulceration due to a large surface area, lateral protrusion of the globes, and environmental conditions that present a wide range of corneal weapons. Equine corneal ulceration is the most common ophthalmic condition a practitioner will see in the field. Most corneal traumas produce a simple surface abrasion that heals within a few days. If corneal healing is rapid, optimal ocular function, corneal clarity, and comfort will be restored.¹ However, other traumas are more extensive, threatening corneal integrity. Not all ulcers are simple to treat, and owners may not always seek prompt veterinary attention. Complications to healing may occur due to corneal infection, keratomalacia, disruption in epithelial adhesion, and other pathologies.

Infection can be one reason that a corneal ulcer fails to heal. Clinical signs of an infection such as corneal cellular infiltrate, stromal loss, corneal melting, and significant uveitis warrant diagnostics to check for the presence of pathogens. Selection of antimicrobial treatments should be based on cytology and culture. Cytology is a simple procedure that provides rapid information to guide rational selection of antimicrobials and other appropriate therapy. Culture is recommended for all cases of

slow healing corneal ulceration with cellular infiltrate, stromal loss, or keratomalacia. Please see notes by Dr. Ann Dwyer on cytology of the equine cornea for recommendations on sampling and interpretation.²

It is important to realize that not all corneal ulcers are infected, and that many noninfectious pathologies can cause an ulcer to be slow to heal. All corneal ulcers require careful examination and appropriate diagnostic tests to assess presence or absence of infection and determine whether the ulcer is accompanied by corneal mineralization, eosinophilic infiltrate, keratomalacia, or corneal edema. Selection of rational therapy should be based on a thorough understanding of corneal healing principles and on evaluation of the pathologic profile of the case. Prompt institution of therapy targeted for the specific examination findings, coupled with selection of an effective route and schedule of treatment administration will decrease healing time and optimize clinical outcome.

Corneal Epithelial Wound Healing

Ulcerations of the cornea normally start to heal within hours of injury. First-tear concentrations of enzymes such as matrix metalloproteinases (MMP)-9 increase. These proteolytic cytokines de-

NOTES

grade the damaged epithelial basement membrane and decrease cellular adhesions to ease epithelial migration. Excessive levels of proteases in the tear film can, however, hinder healing.^{1,3} Damaged epithelial cells go through apoptosis and the epithelial cells at the edges of the wound retract. The healthy epithelial cells surrounding the wound edge flatten out and spread over the denuded surface area. Migration of epithelial cells continues until the wound is covered in a single layer of cells. The rate of cell migration is approximately 0.6 mm a day in a healthy cornea.^{1,4,5}

Healing continues after the wound is covered by a thin layer of epithelium. A proliferation phase occurs next where the normal architecture of multiple layers of epithelium are created. During this phase the corneal barrier function is re-established with formation of tight junctions, gap junctions, and desmosomes between epithelial cells.¹ The final phase is epithelial reattachment when hemidesmosomes reassemble and anchor the epithelium to the anterior stroma.¹ If the epithelial basement membrane was unaffected during the injury this attachment occurs within days, but if the basement membrane was damaged then re-establishment of normal epithelial anchoring can take weeks to months.⁴

Complicated corneal wounds and chronic corneal ulceration often stimulate corneal neovascularization and/or cellular infiltrate. Corneal neovascularization starts 3–5 days after the original injury. Vessels bud from the limbus and migrate at a rate of 1 mm per day toward the wound.⁴ Visualization of vessels allows for a good estimate of the duration of the wound based on the vessel length. Corneal infiltrate is seen as a white or yellow spot that represents a focus of infiltrating neutrophils. These inflammatory cells move into the corneal stroma within the first 12–24 hours of injury and migrate toward the wound at a rate of 8 mm a day.^{1,4,5} Neutrophils liberate proteases that break down damaged tissue and phagocytize cellular and non-cellular debris. Macrophages appear later to remove debris.

Diagnosis of Corneal Ulceration

Clinical signs of ocular pain such as blepharospasm, epiphora, blepharodema, conjunctival hyperemia, and focal corneal edema are highly suggestive of a corneal ulceration, but the diagnosis should not be made without the confirmation of fluorescein stain uptake. Examination of the eye in a dark environment with a cobalt blue light is strongly recommended because small lesions will be missed in a bright environment. Sedation and auriculopalpebral nerve block are recommended to facilitate a thorough examination of the wound and surrounding cornea. Application of fluorescein can be achieved by making a solution of stain by tearing off the orange end of the dye strip and placing it in a 3-cc syringe with 1 mL of sterile saline, then breaking off the needle from the hub and squirting the stain onto the

eye. Alternatively, a moistened dye strip can be touched to the conjunctival surface of the eye. A magnified view of the wound will help the examiner detect any pathologies that are affecting healing.

Pathologies that Affect Corneal Healing

There are many pathologies that affect equine corneal wound healing. It is very important to recognize that many corneal wounds that are slow to heal are not infected, but are complicated by poor cellular attachment, deposits of mineral within the corneal layers, allergic hypersensitivity/eosinophilic infiltration, or endothelial dysfunction. Other subsets of chronic ulcers are complicated by infection with bacterial or fungal pathogens, and/or progressive keratomalacia. A correct diagnosis coupled with institution of rational therapy will decrease the duration of ocular pain, decrease treatment time, and cost and optimize the clinical outcome.

Indolent (Nonhealing) Ulcer

Etiology

A nonhealing corneal ulcer or indolent ulcer is a superficial ulcer that does not heal because the epithelial cells fail to adhere to the anterior stroma. There is abnormal adhesion due to the failure of regeneration of the epithelial basement membrane and dysfunction of hemidesmosome attachments of the epithelial cells to the stroma. In some histology samples of equine nonhealing ulcers there is a hyaline membrane covering the ulcer bed that prevents the interaction needed to restore a healthy junction between the epithelium and stroma.^{1,6,7} Repeat trauma to the epithelial basement membrane and anterior stroma due to the presence of an eyelid foreign body, eyelid suture, or subpalpebral lavage footplate can also occasionally cause nonhealing ulcers.

Diagnosis

A nonhealing or indolent corneal ulcer is observed clinically as a painful eye with a distinct corneal haze. This area of corneal haze will have fluorescein retention and stain will leak between the non-adherent epithelium and stroma under the edge of the obvious area of epithelial loss (Fig. 1). Repeat examination 2–3 minutes after applying the stain to the defect will demonstrate expansion of the area of stain uptake under the loose edge. The vascular response is variable and if present, slow, but often thin, branching vessels are observed with chronicity. There must be absolutely no stromal thickness loss for the diagnosis of an indolent ulcer. Indolent ulcers are not infected; it is important to confirm the absence of pathogenic organisms with cytology and culture prior to instituting treatment.

Treatment

The eyelids and conjunctiva should be inspected to check for any foreign body, hair, suture, or foot plate



Fig. 1. Nonhealing ulcer showing fluorescein stain diffusion under the loose epithelial edge.

that might be abrading the cornea; if any are found, the offending object should be removed. Cytology should be performed to confirm absence of infection. Loose epithelium should be debrided with a series of dry sterile cotton tip applicators after topical anesthetic instillation. Cotton-tip debridement will not disturb healthy epithelial cells that are adhered to the stroma but loose cells will exfoliate due to friction produced by a dry swab. Multiple sterile cotton tips will be required for thorough debridement, as tips that become soaked with tears will not be effective. An additional step that can help disrupt the basement membrane is to use the handle end of a scalpel blade to scrape the lesion. The debrided wound bed is then treated with broad-spectrum topical antibiotics and anticollagenase therapy. Ocular pain is treated with topical atropine and systemic NSAIDs. The ulcer should be rechecked in 1 week. If the ulcer is smaller at that point, topical and systemic treatment is continued and the

lesion is rechecked again in 1–2 weeks. If the lesion is unchanged at 1 week then diagnostic tests should be repeated to look for complicating factors.

Cotton-tip debridement should be the first line of treatment for an indolent ulcer in the field. If the ulcer has not decreased in size after 2 weeks, then referral is recommended.

The treatment options that can be offered by referral centers or clinicians with extensive experience in ophthalmology include a diamond-burr keratotomy or a grid keratotomy. The diamond-burr keratotomy is the current treatment of choice to remove the nonadherent epithelial cells and disrupt any hyaline membrane over the stroma.⁸ There is little risk of causing severe damage to the cornea with the diamond burr unless there is infection in the stroma. There is a slight risk of a thermal burn, which may be avoided with conservative burring technique. The use of a grid keratotomy was a common treatment several years ago but is now strongly discouraged in the horse, and has largely been replaced by the diamond-burr procedure. The grid procedure involves using a sterile needle to excoriate the anterior stroma in a checkerboard pattern. Serious risks associated with this procedure include dragging a surface infection into the anterior stroma along the grid marks¹ and inadvertent puncture of the cornea with the needle. If multiple attempts to stimulate epithelial adhesion have failed, the last treatment option is a superficial keratectomy. Superficial keratectomy removes the anterior stroma to allow regeneration of the stroma, epithelium basement membrane, epithelium, and adhesion complexes.

Medical treatment after a corneal debridement, keratotomy, or keratectomy is used to prevent infection, speed healing, and relieve discomfort. The topical antibiotic selected should be broad spectrum and minimally epitheliotoxic, such as neomycin/polymyxin/bacitracin, erythromycin, or oxytetracycline (Table 1). Oxytetracycline ointment has the added benefit of anti-protease activity.¹ The addi-

Table 1. Treatments for Simple, Indolent, Mineral, Eosinophilic, or Corneal Edema Ulcerations

Class	Drug	Spectrum ^{10,11}	Cidal/Static ^{10,11}	Oint/Sol	Frequency	Compound
Antibiotic	Neomycin	G- >G+	Cidal	Oint/Sol	q 6–8 h	
	Polymyxin B	G-	Cidal	Oint/Sol	q 6–8 h	
	Bacitracin	G- <G+	Cidal	Oint	q 6–8 h	
	Gramicidin	G- <G+	Cidal	Sol	q 6–8 h	
	Oxytetracycline	G- and G+	Static	Oint	q 6 h	
	Erythromycin	G- <G+	Static	Oint	q 6 h	
Antifungal	Silver sulfadiazine		Cidal ¹²	Oint	q 6–8 h	
	Itraconazole/DMSO		Static	Oint	q 6 h	Compound
	Miconazole		Static	Oint	q 6 h	Compound
Cycloplegic	Atropine			Oint/Sol	q 24–48 h	
Antiprotease	Serum			Sol	q 6–8 h	
	EDTA			Oint/Sol	q 6–8 h	Compound

G-, Gram negative; G+, Gram positive, Oint, ointment; Sol, solution.



Fig. 2. Corneal mineralization with signs of equine recurrent uveitis.

tion of serum will decrease the tear-film protease activity. Antifungal treatment is also strongly recommended in any corneal ulcer to diminish the risk of fungal invasion. Topical atropine is a topical cycloplegic that will decrease ciliary spasm and pain induced by secondary uveitis from the corneal ulcer. Systemic NSAIDs are recommended to decrease inflammation and improve comfort, but the lowest dose that keeps the horse reasonably comfortable is recommended. A corneal contact lens can help improve corneal discomfort by stopping the mechanical abrasion of the eyelids over the wound.⁹

Corneal Mineralization

Etiology

Corneal mineralization is a degenerative disease resulting in spontaneous dystrophic calcification. Calcium deposits will occur in the anterior stroma or epithelium. This condition is observed in patients with recurrent anterior uveitis and most often associated with topical steroid use. Corneal mineralization deposits are also observed in chronic and recurrent keratitis.

Diagnosis

The clinical appearance is that of multifocal white, crystalline, or semi-refractile opacities that are often found in a horizontal pattern across the central or ventral cornea.¹ The dorsal cornea is rarely affected. Under magnification the surface of the mineral may look rough or some foci may be sitting above the epithelial surface. Examination of the anterior segment will often reveal signs of recurrent uveitis such as iris hyperpigmentation, corpora nigra atrophy, and posterior synechiae (Fig. 2).

Corneal mineralization can result in a nonhealing corneal ulceration. The mineral deposits can fracture resulting in single or multiple areas of linear or

punctate stain uptake. Fluorescein stain can sometimes adhere to the roughened surface of the mineral. Prior to fluorescein application these areas can autofluoresce under cobalt blue light.

Occasionally, the cornea responds to this mineralization by sloughing the deposit creating a larger corneal ulcer. These ulcers often heal without much difficulty but the resultant significant stromal loss may heal with a corneal facet. A corneal facet is an area of stromal loss that has healed with a covering of epithelium but has not filled in the stromal defect. Anterior and midstromal facets are of little concern but deep stromal facets are at great risk to rupture.

Treatment

Patients that are nonpainful can be treated with a topical calcium chelator like ethylenediaminetetraacetic acid (EDTA) 1–3% q 12 h. EDTA can be compounded as an ointment or made up as a solution in the field by taking a purple-top vacutainer tube and filling it halfway with sterile water.⁴ Higher concentrations of EDTA may induce discomfort in some horses. This treatment is most effective in reducing new mineral deposit formation.

Patients that are painful and ulcerated can be treated conservatively with topical antibiotic, antifungal, and pain management. If the ulcer has not healed after 2–3 weeks of therapy, then debridement of the mineral is recommended as the mineral deposits can create a barrier for epithelium adhesion and migration. A cotton-tip applicator debridement is not effective for removal of the mineral, so the handle end of a sterile scalpel blade can be used to aggressively chip off the mineral. The most effective way to remove superficial mineral is debridement with a diamond-tip burr. If the mineral is deeper than the surface of the stroma, debridement may not be effective. Sometimes the epithelium will heal over the stromal mineral but these patients are still prone to recurrent ulcerations. Referral for surgery to remove the anterior stroma via a superficial keratectomy is recommended in these cases.

All patients with corneal mineralization should discontinue topical steroids. Topical NSAIDs should be used to help control the anterior uveitis and keratitis conditions. The use of daily topical EDTA 1–3% q 12 h is recommended for patients that develop new mineral deposits.

Eosinophilic Keratitis

Etiology

The underlying etiology of eosinophilic keratitis (EK) or keratoconjunctivitis is unknown, but is thought to be a reaction to an allergic or parasitic stimulus. This reaction results in mast-cell degranulation that brings eosinophils to the cornea and the eosinophilic granule proteins induce severe inflammation and inhibit wound healing.^{13,14} This



Fig. 3. EK with an ulcer on the medial limbus.

condition is recognized worldwide with regional and seasonal variations. The condition may be seen in one or multiple horses on the same farm.¹⁵

Diagnosis

EK presents initially with blepharodema, chemosis, conjunctival hyperemia, caseous ocular discharge, and varying degrees of ocular discomfort of one or both eyes. In some horses the eyelids are so swollen that examination of the cornea is limited. Corneal lesions may be present behind the third eyelid but may be difficult to visualize (Fig. 3). Corneal lesions always start at the limbus with the ventral medial and lateral locations most commonly affected. Multiple lesions in the same eye can occur and extension into the axial cornea is often observed with larger lesions (Fig. 4). The corneal lesions are superficial ulcerations with a dull gray plaque or white to pink caseous plaque appearance. These ulcers often have faint fluorescein stain uptake that can be missed without a cobalt blue light. Corneal vascularization is variable but most often intense and rapidly progressive.

The diagnosis is based on clinical presentation, ulceration appearance, and is confirmed by corneal cytology, which will demonstrate an inflammatory response with numerous eosinophils interspersed among corneal epithelial cells and infiltrating neutrophils.^{15,16} Bright pink refractile granules may also be observed on the slide. Late in the disease when there is a chronic superficial ulceration, eosinophils may no longer be observed on cytology. In the chronic stages of the ulceration the patient is often very comfortable, requiring little to no pain management. Horses that present with a small

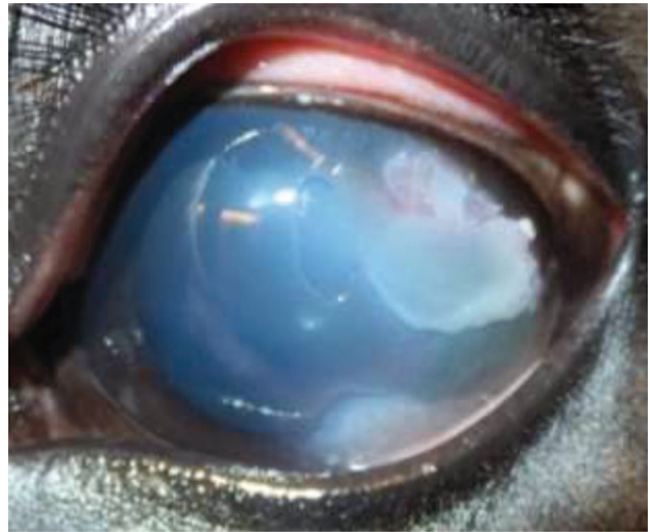


Fig. 4. EK with two perilimbal ulcerative dull gray plaques.

corneal EK lesion may not show discomfort. Keratoconjunctivitis sicca, lacrimal adenitis, and corneal infections can also occur with EK.^{15,17} Increased ocular discomfort in a patient with EK often suggests a secondary bacterial or fungal infection (Fig. 5).

The hallmarks of this condition that should raise suspicion are blepharodema with caseous discharge and limbal-based corneal ulcerations associated with plaques. Ocular discomfort is variable but frequently minimal. Bilateral disease and multiple lesions per eye are strongly suggestive of EK. EK ulcer healing is prolonged, often taking months for resolution. Recurrence of the condition in subsequent years has been observed in up to one third of patients.¹⁵

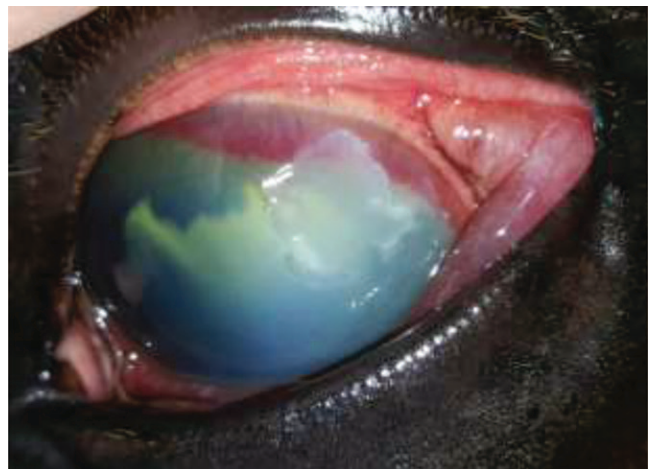


Fig. 5. EK plaque with a secondary infection.

Treatment

Treatment for EK is aimed at reducing the inflammation and eosinophilic reaction that is delaying wound healing, preventing corneal infection, and decreasing recurrence. Medical treatment with broad-spectrum topical antibiotics and antifungals is strongly recommended to prevent corneal infection during the prolonged healing time. The inflammatory response is best treated systemically as topical steroids and NSAIDs increase the risk of corneal infection. However, some clinicians will use a *short* course of topical steroids or a topical NSAID on confirmed EK cases even though corneal ulceration is present. If such treatment is chosen, the horse should be monitored closely for infection. To limit the use of topical steroids a short tapering course of systemic steroids is recommended,¹⁵ often starting with 20 mg dexamethasone q 24 h, tapering every 3 days. Not all horses are candidates for systemic steroid use due to the greater risk of laminitis in patients with metabolic or Cushing's disease; therefore, the clinician must weigh the risks for each patient. Patients that are not candidates for systemic steroids can be treated with oral antihistamines such as cetirizine 0.4 mg/kg q 12 h.

Medical treatment for nonhealing corneal ulceration associated with EK can take months of topical medications but corneal debridement can help speed healing. Cotton-tip debridement does not provide enough friction to disrupt the epithelial basement membrane and promote healing. Instead, the handle end of a sterile scalpel blade is recommended to scrape plaques and loose epithelial cells off the existing ulcer beds. Diamond-tipped burr debridement may hasten healing by removing the abnormal basement membrane and residual eosinophilic granule proteins¹⁴ and may promote re-epithelialization of EK ulcers in just 2–3 weeks. If these debridement techniques do not result in healing and there is a static painful corneal ulceration, then a superficial keratectomy is recommended to remove the abnormal stroma and epithelium. Superficial keratectomy is commonly followed by resolution of chronic EK corneal lesions within 2–3 weeks.

Pain management for the EK ulcer is variable. Most horses need very little systemic NSAIDs and topical atropine to maintain comfort. Horses that need significant pain management are likely to have a secondary infection and referral for superficial keratectomy is recommended. Cetirizine and constant fly mask protection are recommended during the buggy season to reduce recurrence of EK. Oral cetirizine dosing at 0.4 mg/kg q 12 h has been shown to significantly decrease repeat episodes.¹⁵

Corneal Edema

Etiology

Corneal edema is the accumulation of fluid in the corneal stroma. Clinically corneal edema present as a focal or diffuse pattern of corneal haziness and



Fig. 6. Endotheliitis with multiple keratic precipitates and focal corneal edema.

will have varying degrees of severity. Normally, fluid is blocked from accumulating in the stroma by an intact corneal epithelium and endothelium. Corneal ulcerations cause stromal edema as epithelial loss allows fluid to penetrate the corneal stroma demarcating the area of corneal ulceration. Corneal endothelial disease will result in corneal edema as well, and can cause focal corneal ulceration.

The corneal endothelium has two main functions: to decrease stromal aqueous humor penetration and to pump fluid out of the corneal stroma.¹ The tight junctions between endothelial cells decrease the penetration of aqueous but do not block osmotic transfer of water, solutes, macromolecules, and nutrients in to the stroma.¹ Each endothelial cell has an active ion-water transfer pump dependent on Na⁺/K⁺-ATPase to help keep the stroma relatively dehydrated.^{1,5}

Corneal edema can be the result of focal or diffuse endothelial dysfunction and can lead to corneal ulceration. Focal endothelial dysfunction occurs when there is segmental disruption of the endothelial basement membrane or a linear break in Descemet's membrane. This edema will often resolve as the endothelial fracture heals, leaving a linear corneal striae as a footprint.¹ Focal endothelial dysfunction can also occur when keratic precipitates or fibrin accumulate in a specific region, secondary to anterior uveitis or regional endotheliitis (Fig. 6). Diffuse corneal edema can be due to diffuse endotheliitis, uveitis, or glaucoma (Fig. 7).

All of these diseases can lead to focal or diffuse corneal edema that can result in superficial ulcerations due to corneal bullae (Fig. 8). Bullae are a focal corneal epithelial response to moderate-to-severe corneal stromal edema and manifest as small epithelial blisters that contain fluid. Bullae that rupture create punctate ulcerations on the corneal surface (Fig. 9). Clusters of these punctate defects



Fig. 7. Glaucoma with diffuse edema and multiple large bullae, intraocular pressure (IOP) 62 mm Hg.

can coalesce, leading to a larger region of corneal ulceration.

Diagnosis

A prominent clinical sign that suggests that endothelial dysfunction and stromal edema is the cause of an ulceration is a larger area of edema than expected for the size of the ulcer. Other findings may include focal or diffuse keratic precipitates (tiny white-to-tan foci of inflammatory cells that adhere to the endothelial surface), corneal striae (a pair of parallel lines approximately 1 mm apart along the endothelium crossing the cornea), or signs of anterior uveitis or glaucoma. Bullae or epithelial blis-



Fig. 8. Moderate endotheliitis with multiple small bullae and superficial ulcer.

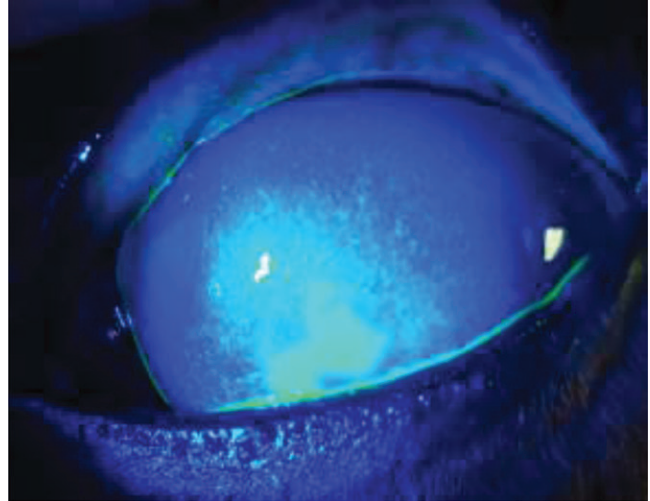


Fig. 9. Fig. 8 viewed under cobalt blue light, showing multiple ruptured bullae.

ters are best seen under magnification but can also be illuminated with fluorescein stain, which will demonstrate punctate patches of uptake where bullae have ruptured (Fig. 9). In some patients, clusters of bullae coalesce as superficial abrasions with a distinct geographic shape (Figs. 8 and 9). These ulcers can be difficult to heal as persistent edema results in new blister formation and because the anterior stroma is not healthy enough for appropriate epithelial adhesion.

Treatment

The treatment for the corneal ulcerations due to endothelial dysfunction and stromal edema is to reduce fluid accumulation and support endothelial function. Once the corneal edema has improved the corneal ulcer should heal quickly, but an indolent ulcer can form due to poor epithelial adhesion. Patients with anterior uveitis will have improved endothelial function with reduction of uveitis and fibrin. Topical NSAIDs and atropine will help control ocular inflammation in these patients, but the use of topical steroids in these patients can lead to infected corneal ulcers, so systemic steroids are recommended. In patients with glaucoma, a reduction in the intraocular pressure will improve corneal edema by decreasing the hydrostatic pressure on the endothelium. Glaucoma complicated by corneal ulceration is treated with systemic anti-inflammatories, topical NSAIDs (diclofenac, flurbiprofen, or bromfenac), and topical timolol/dorzolamide. Laser ablation of the ciliary epithelium is recommended for better control of the intraocular pressure.

Patients with temporary edema due to trauma or corneal striae formation can be treated with systemic anti-inflammatories and topical NSAIDs. Patients with chronic edema from indolent or recurrent ulcers due to endothelial dysfunction will benefit from debridement or surgery. Debridement is

recommended to remove nonadherent epithelial cells and create a stromal bed that promotes adhesion (see notes on debridement of the nonhealing ulcer). The goal of surgery is to decrease current edema and new edema, and increase corneal fibrosis and neovascularization. Referral to a specialist for thermokeratoplasty, or superficial keratectomy with or without a conjunctival inlay graft is recommended for cases that persist after debridement.

All ulcers that accompany corneal edema need broad-spectrum topical antibiotics and antifungals to prevent a corneal infection. Topical 5% hypertonic saline ointment, such as Muro-128, can be used to create an osmotic gradient across the epithelium and draw fluid out of the stroma.¹ This concentrated salt ointment can sting an open corneal wound and should be given separate from other topical medications that are intended for epithelial penetration.

Corneal Infection

Etiology

Equine corneal ulcerations are prone to infection due to environmental contaminants, human fomites, and changes in ocular surface flora. Environmental contaminants can be introduced at the time of injury when a foreign body pierces the corneal surface or the open wound is exposed to dust and dirt. Veterinarians can play a role in infecting the cornea by applying medications without gloves and/or not properly preparing the periorcular area before diagnostic and treatment procedures. Ocular surface flora can vary depending on the age of the horse, time of year, housing conditions, and geographic area. The use of topical antibiotics can disrupt the balance of the ocular microflora allowing pathogenic or non-pathogenic bacterial overgrowth.^{1,18-20}

In the horse the most serious corneal infections are due to *Staphylococcus*, *Streptococcus*, or *Pseudomonas* bacterial species and *Aspergillus* or *Fusarium* fungal species.^{1,21-25} The clinical appearance of the ulceration does not identify the specific pathogen, but certain clinical findings may be correlated with the etiology.

Diagnosis

Clinical suspicion of an infection is based on the presence of ocular pain, infiltrate, stromal loss, vascular pattern, and degree of uveitis. Bacterial ulcers can present with stromal infiltrate (Fig. 10) or no infiltrate. Infected ulcers often have an intense deep or superficial vascular pattern (Fig. 10). Bacterial infections can lead to keratomalacia with gelatinous stroma hanging from the corneal surface. Keratomalacia can occur quickly and within a few hours a superficial ulcer can become a corneal melting ulcer.



Fig. 10. Superficial ulcer with a ring of yellow stromal infiltrate, band of superficial vessels, and miotic pupil.

Fungal ulcers present with varying clinical signs and are often more painful than expected for the size of the corneal lesion. Fungal ulcers are often slow to vascularize. They can present with no infiltrate or demonstrate a prominent stromal infiltrate. Often fungal ulcers have a superficial raised plaque that can be yellow, white, or brown in color. The plaque may be bordered by a deep groove of stromal loss that resembles a moat around a castle (Fig. 11). The defect is the result of the local process that is trying to slough the plaque, but the deep groove can quickly progress to corneal perforation. Fungal ulcers will often get more painful soon after topical antifungal therapy is initiated as the fungal die off causes more inflammation. These ulcers can have

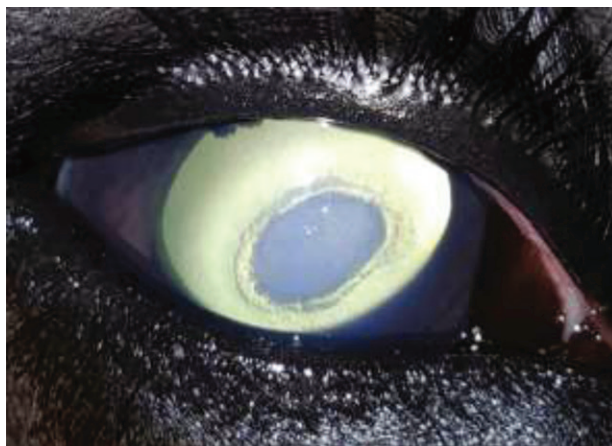


Fig. 11. Superficial fungal plaque with beginning of a groove around the plaque and poor vascular response.



Fig. 12. Sloughing central corneal fungal lesion with distinct groove and poor vascular response.

soft or melting stroma but mostly have sloughing of the stroma (Fig. 12).

Cytology is essential to confirm the type of microbial infection and to help guide topical treatment. Culture and sensitivity is recommended to identify the microbe and adjust topical treatment if the cornea is not improving. The New Bolton Center Microbiology Laboratory has a topical ocular sensitivity panel that tests pathogen sensitivity to various commercially available and compounded antibiotics, using a Kirby-Bauer technique.

Treatment

Rapid institution of aggressive topical treatment of corneal infections with appropriate antimicrobials may circumvent the need for surgical intervention. Selection of antimicrobial(s) should be based on results of cytology and culture. All patients require broad-spectrum antibiotic coverage but cytology will direct how much Gram-positive or Gram-negative

coverage is necessary. All patients should receive antifungal coverage but cytology will determine the type of antifungal and dosing frequency. Infected ulcers require treatment with a cycloplegic to achieve mydriasis. As tear-film protease activity is usually very high in infected ulcers, aggressive anti-protease activity should always be instituted. See Table 2 for commonly used topical treatments for corneal infections with notations on agent spectrum of activity, format, dosing, and adverse effects.

Keratomalacia and Stromal Loss

Etiology

The maintenance of corneal health and wound healing depends on balance of proteolytic enzymes and their inhibitors. Corneal melting or keratomalacia occurs when excessive proteolytic enzymes are present in the precorneal tear film, or released by corneal epithelial cells, keratocytes, infiltrative inflammatory cells or infectious organisms. Neutrophil elastase (NE) is produced by leucocytes and digests stromal collagen.^{1,3} MMPs, specifically MMP-2 and MMP-9 are gelatinases that are found at increased levels in equine tears after acute corneal ulceration. These proteinases decrease as the wound heals.^{1,3} Corneal bacterial infections with *Streptococcus* and *Pseudomonas* species trigger the most dramatic melting due to very high levels of tear film and stromal proteases²⁶⁻²⁷ and are frequently associated with rapid liquefaction and/or perforation.

Diagnosis

The diagnosis of keratomalacia is made upon observation of soft corneal stroma, stromal loss, or protruding gelatinous stroma (Fig. 13). Corneal ulceration is confirmed with fluorescein stain uptake and gelatinous cornea is demonstrated by using the motion of the eyelid to move the soft or protruding cornea. Stromal loss can be observed as a divot or depression in the corneal surface (Fig. 14). The amount of stromal loss can be estimated using the

Table 2. Common Ophthalmic Topical Treatments for Corneal Infections and Keratomalacia

Class	Drug	Spectrum ^{10,11}	Cidal/Static ^{10,11}	Oint/Sol	Frequency	Side Effect ¹¹	Compound
Antibiotic	Chloramphenicol	G- and G+	Static	Oint	q 4-6 h	Anemia	Compound
	Ciprofloxacin	G- and G+	Cidal	Sol	q 2-4 h	Deposits	
	Ofloxacin	G- and G+	Cidal	Sol	q 2-4 h		
	Moxifloxacin	G- and G+	Cidal	Sol	q 2-4 h		Compound
	Cefazolin	G-<G+	Cidal	Sol	q 2-4 h		
	Tobramycin	G-	Cidal	Oint/Sol	q 2-4 h		
	Gentamycin	G->>G+	Cidal	Oint/Sol	q 4-6 h	Epithelio-toxic	
Antifungal	Voriconazole		Static	Sol	q 4-6 h		
	Natamycin		Cidal	Susp	q 4-6 h		
Cycloplegic	Atropine			Oint/Sol	q 8-12 h		
Antiprotease	Serum			Sol	q 1-2 h		
	EDTA			Sol	q 1-2 h		Compound

Cidal, bacteriocidal; Compound, must be compounded because a commercial form is not available; G-, Gram negative; G+, Gram positive; Oint, ointment; Sol, solution; Static, bacteriostatic; Susp, suspension.



Fig. 13. Keratomalacia with hanging soft corneal stroma. The ventral ulcer has a pronounced cellular infiltrate.

slit beam aperture on the direct ophthalmoscope head. As the beam crosses over the defect, the loss of beam thickness compared with the normal surrounding cornea can be estimated. It is difficult to estimate the degree of stromal thickness loss under an area of corneal melting.

Treatment

Corneal cytology and culture should be obtained for all corneal ulcers that have stromal loss or softened cornea. It should be assumed that corneal infection is present; same-day cytology analysis will guide prompt and rational antimicrobial choices that may be sight saving. See Table 2 for commonly used topical treatments for stromal loss and keratomalacia. In addition to topical antimicrobials, the use of

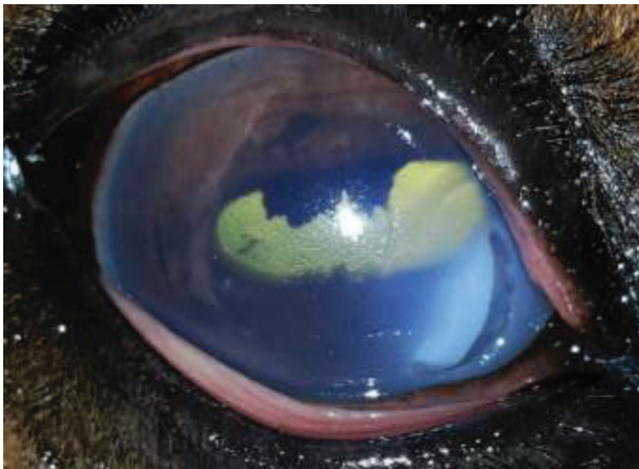


Fig. 14. Stromal loss with surrounding corneal edema and stromal infiltrate.

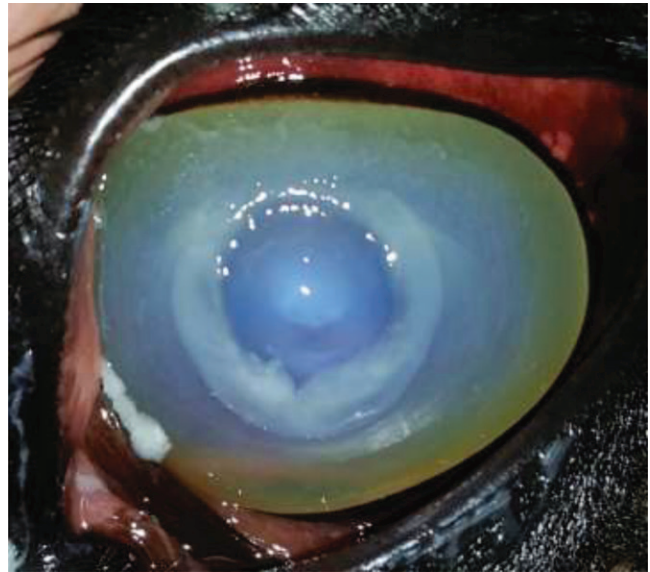


Fig. 15. Large central deep stromal ulcer. This ulcer threatens vision; an amnion graft is recommended.

topical anticollagenases is critical to slow corneal liquefaction. MMPs are inhibited by serum, EDTA, acetylcysteine, and tetracyclines and NE is inhibited by serum, specifically by prealbumin protease inhibitor and alpha-2 macroglobulin.²⁶⁻²⁸ EDTA, tetracycline, and acetylcysteine inhibit MMPs by calcium and zinc chelation, processes that influence enzymatic stability and function.²⁶⁻²⁸

Antiproteases need to be applied topically every 1-2 hours in patients that have keratomalacia or active stromal loss that are being treated medically. Medical treatment should be started immediately and daily monitoring is recommended until the cornea is firming up. If the stromal loss is increasing or the melting is continuing to get worse, referral for a conjunctival graft is recommended. Conjunctival grafts act as a patch over the wound and allow serum, fibroblasts, and vessels to have rapid and direct action on wound healing. Conjunctival grafts are often stable within 2-3 weeks, allowing topical medical therapy to be minimized and discontinuation of pain management therapy. Conjunctival grafts do induce significant corneal fibrosis limiting vision in the area of conjunctival adhesion. Large corneal melts that cover the entire central area of the cornea and threaten vision can be managed surgically with amnion grafts (Fig. 15). Amnion grafts do not bring a direct vascular supply to the wound but act as a disposable dressing that proteases and microbes will attack, decreasing deleterious effects on the cornea.^{1,29,30} Corneal wounds treated with amnion will still result in scar tissue but the density and vascularity of the scar is minimized allowing for much greater vision than a conjunctival graft.

Application of Medications

Topical medications should be applied with concurrent positive reinforcement (oral treats) given before and after every application. Consistent application technique will increase the probability that medications will successfully enter the tear film to treat the ocular surface. A small amount of ointment on the pad of a gloved index finger applied into the medial canthal pocket is a reliable technique in cooperative patients. Ointments can also be applied using a 1-mL syringe loaded with ointment that is then applied to the medial canthal pocket. All horses that are difficult, very painful, or dangerous to treat should have a subpalpebral lavage placed even if the ulcer is a simple ulcer. Horses with stromal loss or keratomalacia must have a subpalpebral lavage placed to avoid placing pressure on the globe and accommodate frequent treatments by multiple people. Subpalpebral lavage systems can be maintained by most clients at home and can be repaired if needed. For horses that require turnout, the tubing system can be protected from breaking by fitting the horse with a “slinky” neck cover (item of equine apparel often used to protect the coats of show horses) and a fly mask. In the warmer weather when a slinky would create excess sweating, a larger gauge tubing can be slid over the smaller lavage tubing when the system is placed to protect the length of tubing that extends from the middle of the forehead to the injection port at the withers.

Application frequency varies depending on the condition being treated. Infected ulcers need frequent topical medication application to reduce the fungal or bacterial burden. Noninfected ulcers need less frequent treatments given that the goal is to prevent infection. Treatment with bacteriostatic drugs should be frequent as these drugs only decrease microbial replication. When multiple topical ophthalmic solutions or suspensions are scheduled for one treatment session, they should be applied at 5-minute intervals to give each medication time to be absorbed before the tear volume turns over at 7 minutes.³¹ Small amounts of ophthalmic ointments can be applied simultaneously, but if the total volume of applied ointment is large some of the medication may not make it to the corneal surface. Splitting the volume of ointment delivery into two applications is recommended when four to five medications are prescribed. Assessment of mydriasis following topical atropine application can be used as a test to determine whether the client can get medications onto the eye successfully. If the pupil is dilated after the owner applies atropine, then most likely the client can get medications onto the eye.

2. Discussion

Equine corneal ulcerations can be one of the most frustrating conditions a veterinarian will treat. Simple ulcers that heal in a few days with minimal treatment are very rewarding, but complicated ul-

cers that do not heal, are infected, and/or melting challenge all clinicians including veterinary ophthalmologists. The best approach for choosing appropriate treatment is to perform a thorough ophthalmic examination of both eyes looking for an underlying etiology of the ulceration. Clinical features that should be assessed include the pattern of corneal edema and neovascularization associated with the ulcer, the presence of stromal loss and/or melting, and whether stromal infiltrate, mineralization, or eosinophilic plaques are present. The examination should detail the number of ulcerations and their location on the cornea, and whether the affected globe shows signs of past or present equine recurrent uveitis. Fluorescein staining must be performed to confirm the extent of ulceration and check for nonadherent epithelium. Corneal cytology is essential to quickly determine whether the wound is infected or has eosinophils and help guide therapy choices. Submission of a corneal sample for culture and sensitivity will guide topical therapy choices in a poorly responding wound; negative culture results will assure clinicians that debridement of an indolent lesion is a safe therapeutic choice. Broad-spectrum antimicrobial therapy should be instituted with drug choices based on formulation, application technique, dosing frequency, availability, and cost. Anticollagenase and mydriatic therapy is essential in most cases. Clinicians should seek consultation with or referral to a veterinary ophthalmologist when corneal ulcers are not responding to therapy, when secondary uveitis is poorly responsive, or in ulcers that demonstrate significant stromal loss or keratomalacia.

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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How to Recognize and Treat Corneal Stromal Abscesses

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1. Introduction

The nonulcerative keratopathy stromal abscess (SA) found in horses is a focal mixture of cellular debris, necrotic collagen, and possibly an infectious agent or foreign body that incites formation of a surrounding reactive inflammatory zone of neutrophils and macrophages¹⁻³ (Figs. 1-5). Dr. Bill Rebhun in 1982 was the first to clinically describe the corneal SA of the horse as a painful sight-threatening condition.¹⁻⁴ The diagnosis of a superficial SA, deep stromal abscess (DSA), or full-thickness SA can be relatively difficult in some eyes with severe iridocyclitis and corneal edema, and is best made by clinical appearance, history, and slit-lamp biomicroscopy. Medical and surgical treatments have developed and evolved over many years for treatment of superficial and deep corneal SA.¹⁻⁴

2. Discussion

Presumed Pathogenesis of Equine Corneal SAs

A number of different hypotheses for the pathogenesis of SA in horses have been proposed.¹⁻⁴ A likely theory for eyes with SA is that a pathogen or foreign body may be trapped in the stroma during the healing process of an infected corneal ulcer, or occur by direct inoculation of the stroma by a mi-

cropuncture through the intact epithelium. It is also possible that some SA could develop in the deeper layer of the corneal stroma via vertical migration of fungi from the superficial cornea to the deeper stroma, and possibly by hematogenous spread of embolic abscess material leaving the iris capillaries to reach the anterior chamber and attach to the corneal endothelium. In this latter proposal, systemic infection could be the cause of DSAs. This latter theory may also explain why a SA in one eye can precede the development of a SA in the other eye, and also why horse farms that have historically never had any horses with SA suddenly experience multiple SA cases.

Thirty years ago most equine SAs were believed to be caused by bacterial infections.⁴ We now know that the most common cause of SA in horses is fungal infection.¹⁻³ Some fungi seem to have an unexplained affinity for the deeper layers of the cornea with fungal organisms often present in or near Descemet's membrane in equine DSA. It may be that these fungi produce high amounts of proteinases that enable them to penetrate deeper into the cornea to cause DSA.

The most common fungi isolated from SA from horses are *Aspergillus*, *Fusarium*, *Candida*, and *Alternaria* spp.¹ The most common bacteria causing

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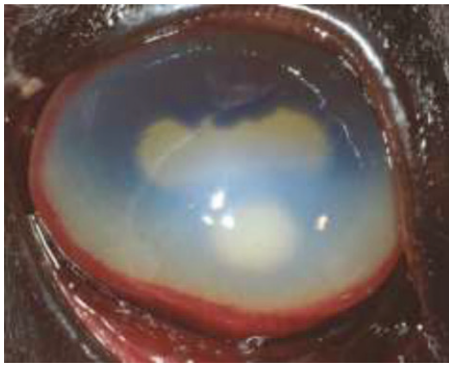


Fig. 1. A circular DSA (yellow) is surrounded by corneal edema (blue). Limbal vascularization (red) is intense in this eye but has not invaded the DSA.

SA in the horse are *Pseudomonas aeruginosa*, beta-haemolytic streptococcal spp. (*Streptococcus zooepidemicus*), and staphylococcal spp.¹

Diagnosis and Differential Diagnoses for SAs in the Horse

The differential diagnosis for a horse with a nonulcerative focal yellow/white corneal opacity include keratic precipitates secondary to uveitis, lens abscess, hypopyon, endophthalmitis, eosinophilic keratitis, a healed stromal ulcer scar, and stromal fungal vesicles.

Stromal abscesses are always painful with the lack of comfort ranging from subtle eyelid drooping to severe squinting. They are generally single but multiple SA can occur. The eye with an early SA will have mild iridocyclitis with miosis and/or a pupil that responds poorly to atropine therapy. Severe anterior uveitis with flare and hypopyon can occur in chronic SA eyes. Corneal edema can surround the SA lesion in early cases or become generalized with time. Vascularization of the cornea may be absent or intense. Asymmetrical corneal vascularization is a hallmark of the SA. Fluorescein retention is not prominent in most eyes with SA.¹⁻³

The diagnosis of a SA is based on the visualization of a focal, yellow-white, corneal stromal infiltrate with associated corneal edema.¹⁻³ Single or multi-

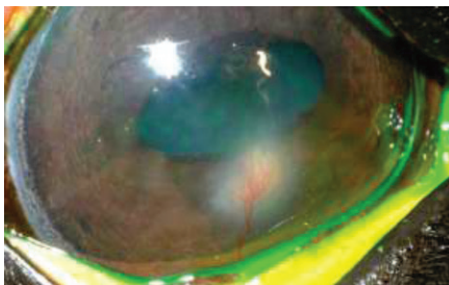


Fig. 2. A DSA with sparse vascularization in the cornea anterior to the abscess partially obscures a good view of the lesion.



Fig. 3. A full-thickness SA with a brighter superficial component and surrounding darker gray deeper abscess is present.

ple abscesses may be present. Fluorescein dye retention is either negative or faintly positive over the SA. A mild-to-fulminating iridocyclitis can occur to cause ocular pain and possible blindness. Corneal vascularization varies according to the stage of SA progression, the presence of fungi, and the length of time the abscess has been present. Vascularization may obscure a good view of an abscess.

Immune Response of the Normal Cornea and the Cornea with a SA

The function of the cornea is to be a transparent, supportive barrier. The transparency is maintained by corneal immune privilege. The cornea does not normally react to immunogenic stimuli in a traditional manner to avoid loss of transparency from the development of edema, neovascularization, cellular infiltration, and fibrosis. However, in the case of DSA, leukocytes (primarily neutrophils and macrophages in the horse) are attracted very aggressively and rapidly for the formation of a SA, suggesting that the immune privilege of the cornea has been lost. An angiogenic and lymphangiogenic response is eventually appreciated in many cases.

The formation of a SA may be divided into three functionally different steps: peracute, acute, and chronic phases.^{5,6} During the peracute phase cellular infiltration can be seen in the cornea with or without ulceration. Vascularization can be seen

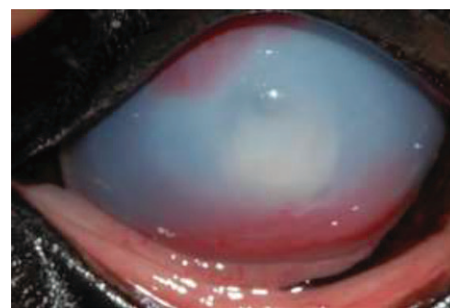


Fig. 4. Large-diameter SA involving the entire corneal thickness is present with edema and prominent limbal vascularization.

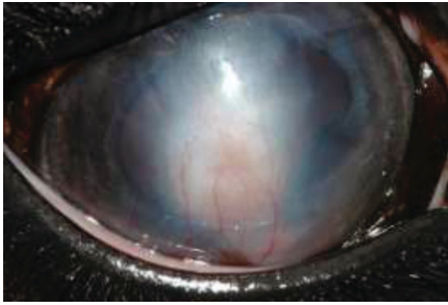


Fig. 5. The eye in Figure 4 healed after 5 weeks of aggressive medical therapy.

moving in from the limbus. This inflammatory response in the cornea will normally also create mild-to-severe anterior segment inflammation or uveitis that manifests as flare, hypopyon, and occasionally hyphema, and a miotic pupil. During the acute phase of SA formation, vascularization is observed in areas of the stroma where cellular infiltration is present. The vascular response in the areas distant from the abscess will be less pronounced, resulting in an asymmetrical vascular pattern. The diffuse cellular infiltration will be consolidated to a smaller, but more dense focal area, and in many cases the cellular infiltrate will migrate to the deeper stroma and Descemet's membrane. The concurrent uveitis will at this point be severe if medical treatment has not been initiated. The chronic phase is characterized by vascularization of the superficial cornea anterior to the SA. For reasons as yet unknown new blood vessels will not easily invade an abscess that is located deep in the posterior cornea. It is possible that cytokines or other chemical agents derived from fungi, bacteria, or leukocytes excrete anti-angiogenic factors that inhibit vascularization of these deep SAs.^{5,6}

The Healing Process of a SA

Vascularization of the abscess and remodelling of the corneal stroma is necessary for healing of SAs.¹⁻³ The purulent material, which in other equine tissues is liquefied, remains firm in most equine corneal SAs and therefore is impossible to drain. If the SA does heal, it does so because blood vessels invade the abscess to induce resolution of the leukocyte response. The vascular response is initially quite robust, but over several weeks begins to attenuate, and results in eventual mild-to-severe subepithelial fibrosis of the stromal lesion. SAs in the anterior stroma are more likely to respond to medical therapy, whereas abscesses of the posterior deep stroma (DSA) and abscesses involving the entire corneal thickness may not respond to medical therapy and thus require surgical removal of the abscess.¹

The pro- and anti-inflammatory mediators, including cytokines, involved in formation, maintenance, and healing of equine SA are currently being

investigated. Vascular endothelial growth factor (VEGF) has been shown to have an important role in the cornea vascularization response in other animal species and could also have an important role in the vascularization process in the horse cornea. Pigment epithelium-derived factor (PEDF) acts in balance with VEGF and is an anti-angiogenesis cytokine that is normally present in the equine retina and in the cornea of other animal species. The presence of PEDF will inhibit vascularization. It is thought that PEDF has a very important role in maintaining the immune privilege of the eye. PEDF may be involved in the absence of vascularization of the surrounding tissue of a SA in the horse. It is possible that a loss of homeostatic balance between VEGF and PEDF may play a role in the absence of vascularization seen in many cases of fungal SAs.^{5,6}

Recent Evidence Concerning Horses in Florida with SAs

The University of Florida found that equine corneal SAs do not often appear in Florida when the weather is severely hot and humid. Instead, SAs tend to develop when the weather is within more "normal" temperature and humidity parameters similar to those in more temperate climates of the world. High periods of increased wind speed also found more horses diagnosed with SA.⁷

Data from Florida horses with SA suggest that fungal organisms are not often found on microbiologic culture of SA samples even though a large number of these cases are suspected to be fungal in origin.^{1-3,5,6} Histologic evaluation of a DSA tissue is needed to determine the true etiology. Microbiologic cultures for bacteria and fungi are still recommended, as well as histopathologic evaluation, to find an etiology and institute proper therapy for equine DSA cases. Polymerase chain reaction has been suggested as a method for recognizing the agent in a cytology sample or surgical biopsy. Confocal microscopy has been shown to be useful as a diagnostic tool for mycotic keratitis, and in the future, these methods may prove useful in providing a more accurate diagnosis of the etiology of DSA in the horse.^{5,6}

Fungal hyphae were found in 47.1% of the DSA cases in Florida horses where the abscess was removed surgically and submitted for histopathology. Most fungal DSAs showed suppurative keratitis (66.7%), and little to no stromal vascularization infiltrating the abscess.^{5,6} All three angiogenesis-related factors were expressed in DSA tissue. Fungal DSA cases from Florida had little to no stromal vascularization suggesting the fungi induce a decreased vascular response to a DSA. A lack of VEGF-A expression in the tissue of these cases with fungal hyphae present in the biopsies suggest an abnormally decreased VEGF-A expression to be the likely reason for the slow vascularization that causes often prolonged resolution of fungal DSA.

It is hypothesized that the antifungal drugs used preoperatively are effective at killing the fungi but the corneal reaction to the fungal death is actually causing the abscess formation. This analysis of biopsies from Florida horses with SA and DSA found that DSA with fungi as the etiology had a negative association with stromal vascularization. A negative association between positive expression of VEGF-A and PEDF, and the presence of fungal hyphae was also found. When fungi were identified in DSA cases as the sole etiology, a suppurative keratitis was found in 75% of the cases. A negative association was found between bacterial growth and suppurative keratitis.^{5,6}

The clinical appearance of DSA with fungi as the etiology was shown to be a focal yellow or white corneal stromal opacity. Suppurative keratitis (predominantly neutrophils) was statistically shown to be the most likely histopathologic diagnosis for fungal SAs, and more importantly, fungi were statistically not associated with stromal vascularization of DSA.^{5,6} The macrophages in the pyogranulomatous form of DSA of horses were more effective at removing hyphae and thus rarely had fungal involvement.^{5,6}

The study of biopsies from Florida horses with SA and DSA found the corneal SA cases with no fungal hyphae present had a significant vascular response with VEGF-A present, whereas the corneal stromal abscess cases with fungal hyphae present lacked corneal vascularization and VEGF-A. It could be hypothesized that the true cause for the decreased vascular response of corneal SAs is an abnormal decrease in VEGF-A expression instead of an abnormal increase in antiangiogenic secretion.^{5,6}

Medical Treatment of SAs

Medical treatment consists of a combination of antimicrobial medications, mydriatic/cycloplegic drugs, and anti-inflammatory medications. Subpalpebral lavage systems may aid aggressive medical therapy. The antimicrobial medication will normally be a combination of antibiotic and antifungal drugs. These topical medications may need to be administered to the cornea between four and six times daily for 4–6 weeks.¹

Medical treatment of superficial SA is most economical and can result in good visual outcomes with mild scarring (Figs. 4 and 5). DSA are, however, often unresponsive to medical therapy. Medical treatment of DSA is the first step to address the uveitis but surgical therapy may be necessary for DSA to most quickly resolve the condition. Signs of early positive healing of a SA would be vascularization of the abscess, although what occurs in some DSAs is vascularization of the stroma anterior to the DSA but not the DSA itself. The DSA in the latter is thus persisting and not healing.¹

The whitish yellow cellular infiltrate of the superficial or DSA will be replaced with beige-to-gray fibrotic tissue during positive SA healing, and uve-

itis will diminish and be more easily controlled allowing reduced doses of systemically administered anti-inflammatory medications. Most horses with superficial SA require only low doses of systemic nonsteroidal anti-inflammatory drugs (NSAIDs) to control uveitis. However, if the SA is accompanied by uveitic flare-ups despite this low-dose NSAID therapy the DSA is still active and the therapy should be increased. A uveitic flare means that either the infectious agent causing the SA has not been eliminated, or that leukocyte-derived cytokines are still present in the cornea, and further medical treatment or even surgical treatment is indicated. During medical therapy, if no signs of recovery can be appreciated, or if the anterior segment inflammation persists despite aggressive medical treatment, surgical options should be considered.¹

Voriconazole is presently recommended as the drug of choice for therapy of SA⁸ and can be ordered as an US Food and Drug Administration–approved, lyophilized bottle and reconstituted with sterile water to make a 1% solution. Voriconazole has been used successfully intrastromally and intracamerally in the therapy of DSA.^{9,10} Voriconazole should be administered carefully in 0.20-mL quantities from syringes. It does not seem to be compatible with silicone infusion pumps. Voriconazole does seem stable when stored in glass vials but is not stable in silicone or plastic reservoirs. Voriconazole does seem stable at temperatures between 23 and 40°C for up to 30 days.^{9a}

A mydriatic/cycloplegic drug such as atropine 1% ophthalmic solution will need to be administered topically between one and four times daily to achieve pupil dilation and cycloplegia. Atropine should be used with caution given that horses treated with atropine have decreased motility of the intestine. This risk should not prohibit the use of atropine for horses given that a mydriatic is essential to treat the often-severe secondary inflammation in the anterior segment.¹

Systemic NSAIDs are also critical in the medical treatment of SA. Flunixin meglumine is the drug of choice for eye diseases in horses. The specific mechanism of the inflammatory response in the anterior segment of the horse is not well described and to date it is not known whether uveitis in the horse is initiated by a Cox-1 or Cox-2 pathway. It is recommended to treat SA horses with an initial dose of 1.1 mg/kg flunixin meglumine every 12 hours IV or PO until the inflammation in the anterior segment decreases. When the horse is comfortable and signs of inflammation are decreased in the anterior segment, the NSAID drug dose may be decreased. It is not recommended to continue a high dose of anti-inflammatory medication for extended periods of time because the anti-inflammatory effects of flunixin meglumine also induce an antiangiogenic effect on the vascularization of the SA.¹ It is usually necessary to continue NSAID therapy through the length of the treatment period for the

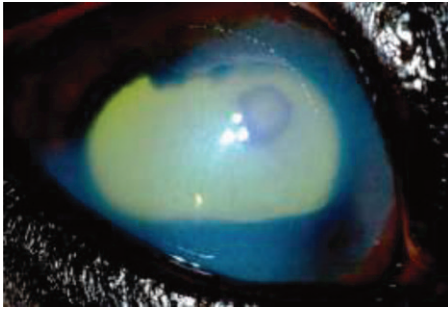


Fig. 6. A full-thickness SA is present.

SA. In many cases, this drug will be the last medication to be discontinued. Omeprazole may be administered to decrease the possibility of gastric ulceration caused by the long-time use of a systemic NSAID medication.

Surgical Treatment for SAs

During the 1980s, surgical treatment of equine SA was more or less condemned because of poor outcome and medical treatment alone was recommended. These recommendations have since changed, medical treatment may need to be continued for months in the DSA. In some cases, anterior segment inflammation cannot be controlled. If there is not a dramatic resolution to the DSA and uveitis after a week of medical therapy it is recommended that surgical alternatives be considered. Various surgical options for surgical removal of SA are available depending on the depth of the abscess in the stroma and the topographic location of the SA in the cornea.

Superficial keratectomy may aid penetration of drugs to the abscess. Superficial keratectomy with conjunctival graft, penetrating keratoplasty (PK), posterior lamellar keratoplasty (PLK), deep lamel-



Fig. 7. Intraoperative appearance of PK graft sutured into place (different eye than Figure 6).

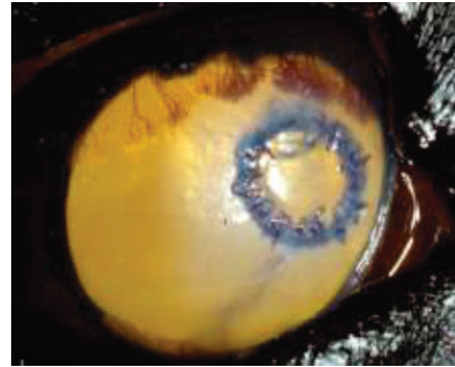


Fig. 8. The PK donor cornea is intact 1 week postoperatively in the eye in Figure 6.

lar endothelial keratoplasty (DLEK), carbon dioxide laser keratectomy with conjunctival graft, and enucleation have been used for eyes with SA.^{2,3}

PK¹⁻³ is full-thickness microsurgical removal of the region of the cornea containing the SA followed by full-thickness transplantation of the corneal epithelium, stroma, and Descemet's membrane/endothelium (Figs. 6-9) Full-thickness penetrating keratoplasty may be performed in horses for therapeutic and tectonic reasons for melting ulcers with extensive stromal loss, iris prolapse/descemetocoeles, and full-thickness SAs. Penetrating keratoplasty has become a viable, routine, and successful surgical technique in horses with severe keratitis, and is associated with a very good visual outcome in most cases (approximately 80%). However, nearly all the corneal transplant-donor allografts in horses vascularize postoperatively and exhibit troubling degrees of corneal opacification at the surgical site.

The concept of lamellar keratoplasty is to target and replace only diseased corneal tissue while retaining the normal healthy corneal tissue.¹⁻³ Lamellar keratoplasty is used for tectonic reasons to replace damaged stroma in melting corneal ulcers of human patients as it provides enhanced donor-graft survival and improved visual outcomes compared

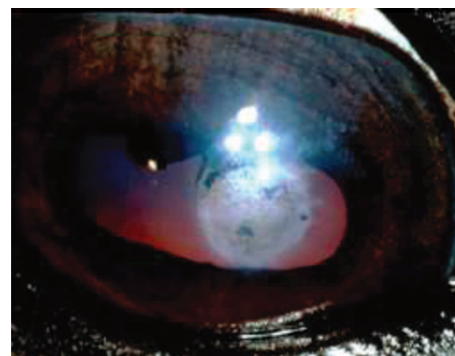


Fig. 9. The eye is visual with some stromal scarring 15 months following PK in the horse in Figures 6 and 8.

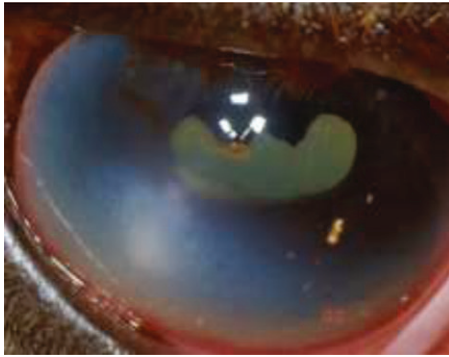


Fig. 10. A DSA and edema are present in peripheral cornea in this horse.

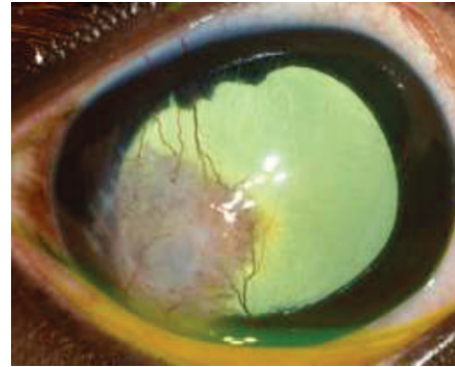


Fig. 12. A healed PLK site is present 6 weeks postoperatively in the horse in Figures 10 and 11.

with PK. DLEK and PLK are split-thickness lamellar keratoplasties used to replace diseased endothelium from bullous keratopathy in humans. The remaining healthy corneal layers are preserved in DLEK and PLK. This targeted replacement of individual diseased components of the cornea also seems suitable for treatment of equine keratopathies. The overall success rates for rapid return to visual function for surgical therapy of DSA by DLEK and PLK in horses are higher than for PK.¹⁻³

PLK (Figs. 10-13) in horses is recommended for DSA in the axial cornea that are 10 mm or less in diameter.¹⁻³ The overlying epithelium may be edematous but is intact, and the anterior stroma may be vascularized but should not have cellular infiltrate. This procedure replaces the diseased posterior stroma and endothelium, and has proven successful for surgical therapy of DSA in the horse. DLEK (Figs. 14 and 15) is a similar technique that is recommended for medically nonresponsive DSAs in the peripheral cornea that are 10 mm or less in diameter, and have moderate vascularization and edema of the overlying epithelium and anterior stroma with no stromal cellular infiltrate. The DLEK transfers healthy Descemet's membrane and endothelium while preserving the corneal surface

and topography. The difference between the PLK and the DLEK is the placement of sutures in the anterior cornea in the PLK surgery compared with only sutures in the limbus when the DLEK surgery is performed.¹⁻³

Visual Outcome for Medical and Surgical Treatment of SAs

The visual outcome for SA depends on whether the healing process has been completed with medical treatment or with one of the surgical approaches.¹⁻³ Less scarring of the cornea can be seen with small DSA treated medically if they respond to medical treatment alone. If this is not possible the PK, PLK, or DLEK is recommended depending on the location and depth of the SA. These surgical techniques will all leave some type of corneal scar, given that a full- or partial-thickness corneal allograft is used to close the corneal defect. It has not been possible to date to inhibit the rejection of the corneal transplant so all grafts become opaque as part of the rejection process. The rejection of the equine corneal graft will be seen as a fibrotic area with vascularization. The graft is used for tectonic rather than optical reasons. The horse will retain vision in the areas outside the graft opacity as long as



Fig. 11. Edema and vascularization of the graft are found several days after PLK in the horse in Figure 10.

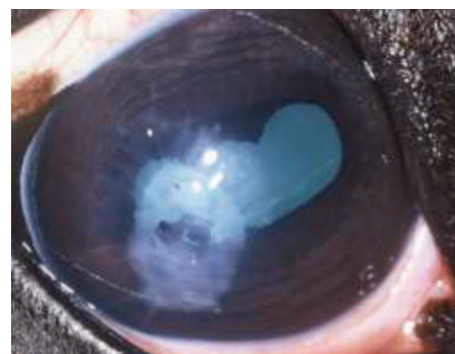


Fig. 13. Five years postoperatively the horse that had PLK surgery in Figures 10-12 was visual and doing very well with slight stromal scarring.

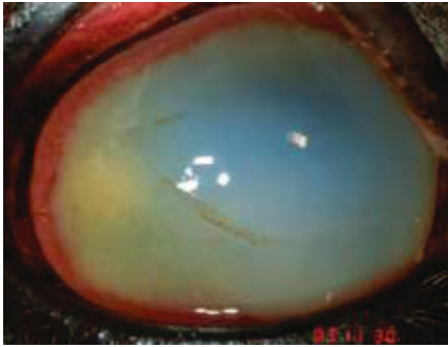


Fig. 14. A DSA is present with edema and intense limbal vascularization. A DLEK surgery was performed.

there has not been extensive damage to the interior from the uveitis. It is not generally recommended to perform a corneal graft surgery with a diameter larger than 12 mm due to scarring if good vision is necessary and expected. Positive visual outcomes from PK surgeries can be achieved in 77.9% of the cases. The positive visual outcome rate from PLK surgeries is near 98.1%, and from DLEK surgeries is 89.4%.¹⁻³

A last medical/surgical procedure for SA is intralaminar injection of the SA with an anti-fungal medication, voriconazole, 1%. This procedure has been performed on standing sedated horses and on horses under general anesthesia.¹⁰ The advantages of this procedure are a lower cost and less invasive



Fig. 15. Fourteen months postoperatively there is only a little corneal haze remaining of the DLEK in the horse in Figure 14.

procedure with less anesthetic risk. The risk of this procedure is the possibility of introducing an infectious agent into the anterior chamber with resultant endophthalmitis.¹⁰

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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^aVFend, Pfizer Inc, New York, NY 10017.

How to Recognize and Manage Equine Recurrent Uveitis

Mary Lassaline, DVM, PhD, DACVO

Obtaining a detailed history and performing a complete and careful ocular examination can facilitate an accurate and potentially more specific diagnosis of equine recurrent uveitis (ERU). Treatment recommendations and follow-up plans should be driven by the specific diagnosis. Client education regarding prognosis and long-term treatment options is critical. Author's address: Department of Surgical & Radiological Sciences, University of California–Davis School of Veterinary Medicine, One Shields Avenue, Davis, CA 95616; e-mail: lasutter@ucdavis.edu. © 2017 AAEP.

1. Introduction

Equine recurrent uveitis (ERU) is the most common cause of blindness in horses, yet its diagnosis can be complicated and treatment variably rewarding. The effect of ERU is significant both in terms of financial cost, vision loss, and loss of use,¹ yet client compliance with monitoring and treatment recommendations are among the most discouraging of common equine ocular complaints that warrant the intervention of a veterinarian.

ERU is an immune-mediated form of uveitis that can result in chronic ocular pain and permanent changes in the eye including cataracts, glaucoma, and retinal detachment. There is no cure for ERU. Treatment is directed at minimizing the frequency and severity of flare-ups, as well as controlling inflammation when it occurs. Standard treatment of ERU includes a topical steroid to reduce inflammation, topical atropine to reduce ciliary spasm, prevent posterior synechiae, and stabilize intraocular vasculature, and a systemic non-steroidal anti-inflammatory (NSAID).² To minimize the frequency and severity of flare-ups of uveitis, an implant was

developed to provide continuous low-dose local delivery of cyclosporine to the eye. Cyclosporine is an immunosuppressive medication isolated from a fungal organism that has been used systemically to prevent organ transplant rejection and to treat immune-mediated diseases such as rheumatoid arthritis, psoriasis, and dry eye. The frequency of flare-ups in horses treated with cyclosporine implants was reduced from approximately one per month to approximately one per year.³ The cyclosporine implant takes approximately 6 to 7 weeks after surgery to deliver therapeutic levels of cyclosporine to the eye. Flare-ups of uveitis still need to be treated, even after placement of the implant. Implants are reported to last 4 to 5 years, even longer in some patients.

The effect of ERU on affected horses and their owners was assessed in one retrospective study of 244 ERU patients.¹ Not surprisingly, Appaloosas were overrepresented in this study, making up 24% of the sample. However, a somewhat surprising result was that on initial examination 28% of eyes were already blind, and 11% already had glaucoma, suggesting that ERU is often advanced by the time

NOTES

of presentation for veterinary care. *Leptospira* titers (either aqueous, serum or both) were positive in 46% of 88 horses tested. In terms of outcomes, 29% of included horses were retired from the job performed at the time of diagnosis, and 30% performed at a reduced level. Fifteen percent of affected horses were euthanized and 19% underwent a change in ownership as a direct result of ERU. In this study, ERU had significant effect on horses and owners due to blindness, globe loss, and loss of function.

Understanding prognosis for vision in horses with ERU is an important component of owner education.⁴ In one long-term study of visual prognosis in 160 horses with ERU followed for 11 years, complete blindness was observed in 20% of horses (32/160), with unilateral blindness in 36% (57/160).⁵ Appaloosas and horses seropositive for *Leptospira* were at increased risk for blindness. All seropositive Appaloosas lost vision in at least one eye, and 50% became completely blind; however, 72% of seronegative Appaloosas lost vision at least one eye, with 29% becoming completely blind. In contrast, 49% of seropositive horses that were not Appaloosas lost vision in at least one eye, with 17% becoming completely blind, whereas only 34% of seronegative horses that were not Appaloosas became blind in at least one eye, with 6% becoming completely blind.

The pathogenesis of ERU is an autoimmune response to a cross-reactive microbial antigen, such as one from a *Leptospira* organism, or an auto-antigen derived from intraocular tissue itself.⁶⁻⁸ Although leptospirosis is not always implicated in horses with ERU, having positive *Leptospira* serum titers to either *L. interrogans* serovar *pomona* or *L. interrogans* serovar *grippotyphosa* are negative prognostic indicators for vision in horses with ERU, and thus collecting serum titers may be warranted for prognostic, if not diagnostic, purposes.

One commercial vaccine against leptospirosis has recently become available for horses. This vaccine is not designed, nor labeled, as protection against, or treatment for, ERU, but rather is labeled for use only in healthy horses. However, in one study using a swine leptospirosis vaccine in horses with ERU to evaluate its effect on frequency of flare-ups, days to recurrence, and progression of disease, vaccinated horses were free of flare-ups for a longer interval than unvaccinated horses, although this difference only approached statistical significance.⁹ Serum titers were measured in both vaccinated and unvaccinated horses at the beginning of the study, and a fairly high percentage of horses in both groups had titers >400 prior to vaccination.

Being an Appaloosa is associated with an eight-fold increase in likelihood of developing uveitis and a four-fold increase in likelihood of blindness relative to other breeds, so early diagnosis and treatment are critical in this breed.¹⁰ An insidious form of ERU has been described in Appaloosas that is characterized by persistent low-grade uveitis rather than recurrent episodes of ocular pain.¹¹ Genes in-

involved in coat color have been associated with ERU in Appaloosas, with leopard spotted Appaloosas at increased risk for insidious ERU relative to other horses.¹²

Traditional diagnostics schemes are nonspecific, lumping cases with widely variable disease progression under the general category of ERU. Horses diagnosed with ERU can include cases that vary in symptoms, stage of presentation, etiology, and prognosis. Gilger and Michau were among the first to characterize three clinical syndromes of ERU: "classic," "insidious," and "posterior."¹¹ Classic ERU is characterized by active inflammatory episodes separated by periods of clinical quiescence. It is not always clear that an eye that appears clinically quiet truly has no ongoing inflammation. Insidious ERU, described most commonly in Appaloosas, is characterized by ongoing inflammation that varies in severity with variable overt ocular discomfort that may not be apparent to the owner. Classic and insidious ERU may be descriptions of the same disease process that manifests differently depending on pain tolerance. Posterior ERU, as the name implies, is characterized by posterior segment (including the vitreous, retina, and choroid) inflammation with minimal to no signs of inflammation in the anterior segment (including ocular structures anterior to, and including, the lens). Posterior ERU, described most commonly in Warmblood and draft breeds, can be devastating when no ocular signs are noted until blindness results from cataracts or retinal detachment. Gilger and Michau emphasized the very important point that by definition, ERU is a recurrent disease, and thus a diagnosis of ERU cannot be rendered without more than one episode of uveitis. As a reminder, uveitis in general can be classified by etiology as due to ocular or systemic disease, with immune-mediated disease perhaps considered a separate category, or a subcategory of systemic disease. Uveitis can only be diagnosed as ERU with a history of prior episodes of uveitis, or clinical signs consistent with prior episodes of uveitis, although defining a history of prior episodes can pose a significant challenge.

Fritz and colleagues, in their investigation of the genetic risk factors for ERU in Appaloosas, categorized horses into one of five grades: 1, no observed ocular pathology; 2, persistent ocular discharge that was not associated with nasal lacrimal disease; 3, subtle changes in iris pigmentation suggestive of past inflammation; 4, ocular discharge, miosis, marked depigmentation or hyperpigmentation of the iris and/or glaucoma; and 5, active uveitis as evidenced by aqueous flare, miosis, or fibrin in the anterior chamber. In that study, Grade 5 also was assigned to horses with signs of persistent uveitis including anterior or posterior synechia, cataract, glaucoma, discolored vitreous or peripapillary chorioretinal scarring. Horses given a Grade 4 or 5 were used as the affected sample in this study.¹² This categorization scheme may not perfectly separate

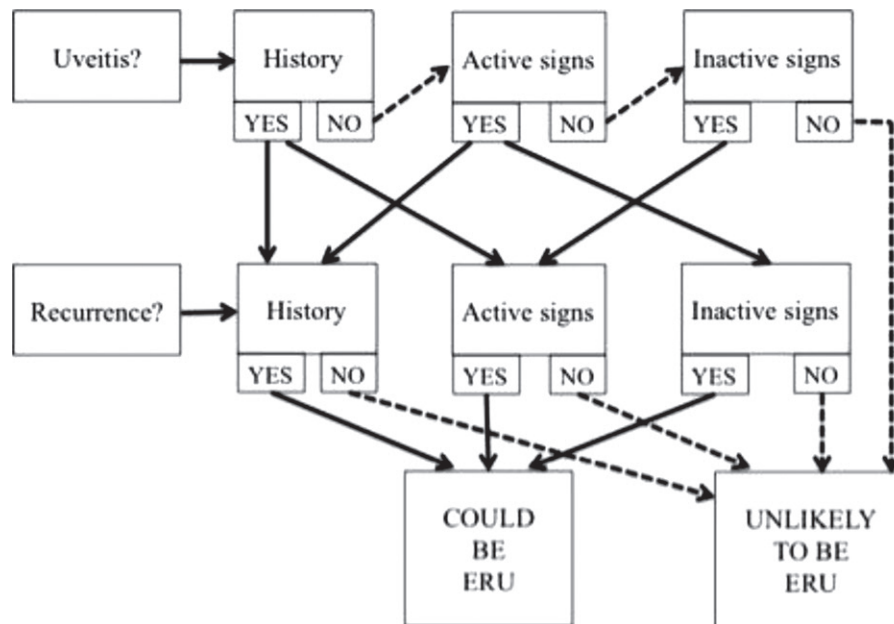


Fig. 1. Decision tree for diagnosis of ERU.

horses that have ERU from horses that do not have ERU, because horses may have active or inactive disease without any history or signs of recurrence. However, the attempt to grade disease severity with specific criteria in a rank-ordered manner is a very important step to better define, and thus improve our ability to diagnose and treat this disease.

The goals of this paper are three-fold: 1) to define a reliable and valid set of diagnostic criteria for horses with ERU, 2) to develop a categorization scheme to capture disease severity and prognosis that would result in assignment of a disease category to each patient diagnosed with ERU, and 3) to present a protocol for therapy and continued monitoring that would minimize cost and maximize compliance and positive outcomes. The mainstay of this approach is clear and documented communication regarding history, clinical signs, categorical diagnosis, and treatment recommendations.

2. Materials and Methods

A systematic approach to ERU diagnosis and therapeutics is proposed, with a decision tree developed to standardize and make explicit each step. A horse may enter the decision tree one of two ways: 1) the presenting complaint is uveitis, and the veterinarian needs to decide if the diagnosis is correct, or 2) the presenting complaint is something more general like red eye, cloudy eye, squinting, or tearing, and the veterinarian needs to decide whether uveitis is the underlying cause. In some sense, the presenting complaint almost does not matter, as the diagnosis of ERU must be based both on history and clinical signs.

To diagnose a horse with ERU, two conditions must be met: the horse must have or have had **UVEITIS**, and the uveitis must be **RECURRENT** (Fig. 1). First, the **UVEITIS** criterion must be satisfied. There are three ways to satisfy this criterion.

1. **HISTORY**: the horse must have had a history of at least one episode of clinical signs consistent with uveitis.
2. **INACTIVE SIGNS**: the horse must have clinical signs that would result from a prior episode of uveitis.
3. **ACTIVE SIGNS**: the horse must be in the midst of an active episode of uveitis at the time of diagnosis.

Second, the **RECURRENT** criterion must be met. This is accomplished by satisfying one of the three uveitis criteria already described (history, inactive signs, or active signs) a second time, with some constraints that ensure that at least two episodes of uveitis have occurred.

1. If the **UVEITIS** criterion was satisfied by **HISTORY**, the **RECURRENT** criterion can be satisfied by either a second **HISTORY** or by **ACTIVE SIGNS**, but not inactive signs, as inactive signs might be a result of the same episode that was captured in the history.
2. If the **UVEITIS** criterion was satisfied by **INACTIVE SIGNS**, the **RECURRENT** criterion must be satisfied by **ACTIVE SIGNS**, but not history or inactive signs,

given that either might be a result of the same episode that resulted in the inactive signs.

3. If the **UVEITIS** criterion was satisfied by **ACTIVE SIGNS**, the **RECURRENCE** criterion can be satisfied by **HISTORY** or **INACTIVE SIGNS**.

More specific information regarding the three ways to satisfy criteria follows.

1. **HISTORY:** Obtain a complete ophthalmic history, including any episodes of squinting, redness, cloudiness, or tearing, regardless of the owner's explanation for the clinical signs (e.g., it is not uncommon for an owner of a horse with ERU to claim that the horse has never had an episode of uveitis, but has allergies). The ophthalmic history should also include a history of any medications, systemic and topical, that have been given to address any ophthalmic complaint.
2. **INACTIVE SIGNS:** After performing a complete ophthalmic exam including fluorescein stain, tonometry, and fundic exam, determine whether any inactive signs suggesting prior uveitis, that may or may not have been detected, are present, including corpora nigra or iris atrophy, anterior or posterior synechiae, iris hyperpigmentation or depigmentation, pigment rests on the anterior lens capsule suggesting prior posterior synechiae, cataract, vitritis, or chorioretinal scar, which could be focal/pinpoint or peripapillary. None of these in isolation are sufficient to diagnose ERU, but they provide evidence that a prior episode of uveitis may have occurred.
3. **ACTIVE SIGNS:** Also subsequent to the complete ophthalmic examination, determine whether any active signs of uveitis are present, including blepharospasm, epiphora, conjunctival hyperemia, corneal edema not associated with a corneal ulcer, corneal vascularization, calcific band keratopathy, aqueous flare, hypopyon, hyphema, miosis, low intraocular pressure, or vitreal haze or opacity, and active signs of chorioretinitis including retinal edema and hemorrhage. Again, none of these are sufficient to diagnose ERU, but they provide evidence that a current episode of uveitis may be occurring.

If both the **UVEITIS** and **RECURRENT** criteria have been met, a diagnosis of ERU can be made. The disease can be further classified as classic, insidious, or posterior,¹¹ with classic and insidious cases determined primarily by history, and posterior cases determined by the physical location of inflammation (i.e., the absence of anterior segment signs). Long-term followup of cases that fall into these three



Fig. 2. ERU Grade 0, normal equine eye. Note normal variation in brown iris pigmentation.

categories may yield prognostic information about the visual outcome and progression of these cases.

A modification of the scheme developed by Fritz and colleagues¹² may provide a categorization scheme to capture disease severity and prognosis that would result in assignment of a disease category to each patient diagnosed with ERU. For example, the following categories are potentially aligned with disease severity and duration:

Grade 0: no observed ocular pathology. See Figs. 2 and 3.

Grade 1: no signs of active uveitis but signs of inactive uveitis are present, suggesting a prior episode (e.g., corpora nigra or iris atrophy, anterior or posterior synechiae, iris hyperpigmentation or depigmentation, pigment rests on the anterior lens capsule suggesting prior posterior synechiae, cataract, vitritis, or chorioretinal scar, which could be



Fig. 3. ERU Grade 0, normal equine eye. Note distinct gray appearance of normal iridocorneal angle at junction of brown iris and white sclera.

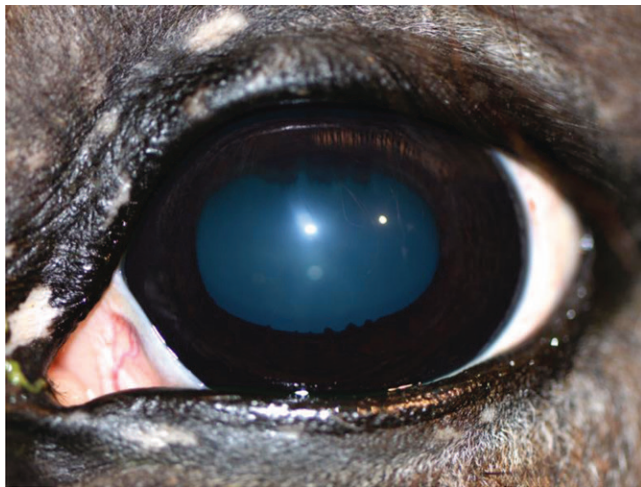


Fig. 4. ERU Grade 1, no active signs of uveitis but iris hyperpigmentation suggesting prior episodes of uveitis.



Fig. 6. ERU Grade 1, no active signs of uveitis but mature cataract is visible as a white opacity involving the entire area of the lens that can be seen through the pupil.

focal/pinpoint or peripapillary, but does not seem to significantly affect vision). See Figs. 4, 5, and 6.

Grade 2: mild signs of active uveitis, particularly those that improve or resolve with short-term traditional therapy (e.g., topical steroid, systemic non-steroidal anti-inflammatory, and/or topical atropine), including mild epiphora, mild blepharospasm or blepharitis, mild conjunctival hyperemia, and subtle miosis (Fig. 7).

Grade 3: moderate signs of active uveitis, including moderate epiphora, moderate blepharospasm or blepharitis, moderate conjunctival hyperemia, mild corneal edema, mild-to-moderate aqueous flare, and moderate to severe miosis, as well as secondary complications including incipient cataracts (Figs. 8–10).

Grade 4: severe signs of active uveitis, including profuse epiphora, severe blepharospasm or blepharitis, severe conjunctival hyperemia, moderate-to-severe corneal edema, severe aqueous flare, hypopyon,

hyphema, profound miosis, and secondary complications including immature, mature, or hypermature cataract, glaucoma, and retinal detachment (Figs. 11–13).

Grade 5: blind “end stage” eye (i.e., phthisis bulbi), which may or may not be associated with chronic pain (Figs. 14 and 15).

Figs. 16 and 17 illustrate an iris color change from blue to yellow associated with active uveitis. The blue color will return to the iris when uveitis resolves. Fig. 18 depicts bullethole lesions, or pinpoint chorioretinal scars, in a horse with ERU.

After a diagnosis of ERU is made, a treatment plan is developed that must include a plan for treating active disease, a plan for monitoring response to therapy, a plan for followup, and a plan for what to do if the patient’s condition changes. The most successful therapeutic plan will consider any pre-existing systemic or ocular conditions that limit the use

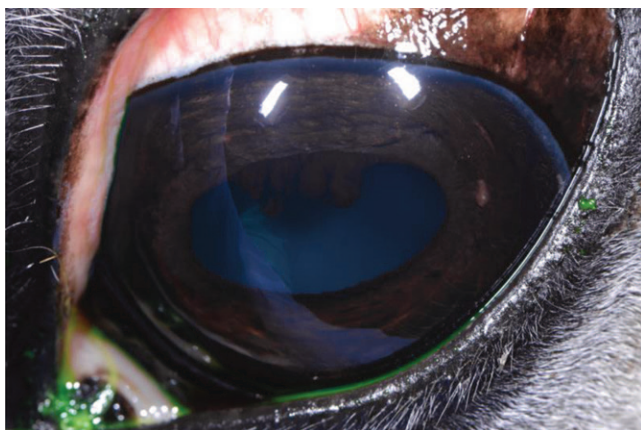


Fig. 5. ERU Grade 1, no active signs of uveitis but uniform dark brown appearance of iris, suggesting iris hyperpigmentation caused by prior episodes of uveitis.



Fig. 7. ERU Grade 2, mild active signs of uveitis as well as iris hyperpigmentation and depigmentation caused by prior episodes of uveitis.



Fig. 8. ERU Grade 3, moderate active signs of uveitis including corneal edema, epiphora (not pictured) and aqueous flare (not visible in this photograph).

of traditional therapy, the owner's interest in and ability to treat the horse, and the owner's financial constraints.

Standard treatment of ERU includes a topical steroid to reduce inflammation, topical atropine to reduce ciliary spasm, prevent posterior synechiae and stabilize intraocular vasculature, and a systemic NSAID. No treatment is necessary for horses classified Grade 0 (no signs of ocular pathology) or Grade 1 (inactive disease only). Both the aggressiveness of therapy and the frequency of recheck examinations to monitor response to treatment should increase as the diagnostic category increases

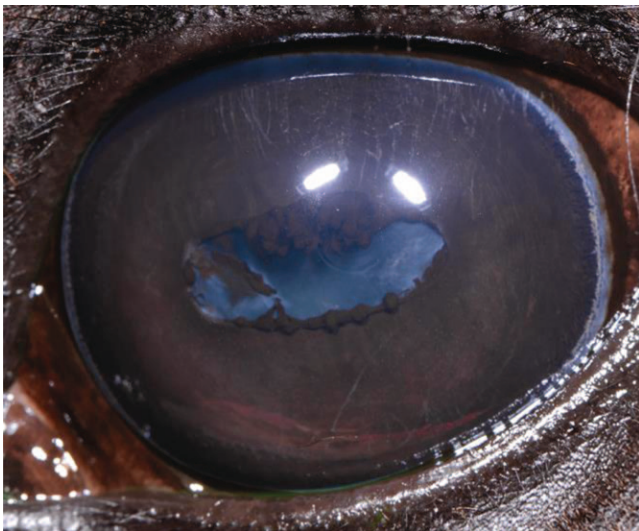


Fig. 9. ERU Grade 3, moderate active signs of uveitis including blepharospasm (not pictured) and epiphora (not pictured) as well as chronic changes including dyscoria, posterior synechia, and mature cataract. This eye retained light perception but not good functional vision.



Fig. 10. Grade 3, moderate active signs of uveitis including blepharospasm (not pictured) and epiphora (not pictured) as well as chronic changes including dyscoria, anterior and posterior synechia, and immature cataract. This eye retained good functional vision.

from Grade 2 (mild active uveitis) to Grade 3 (moderate active uveitis) and Grade 4 (severe active uveitis). For example, a Grade 2 horse might receive a course of a nonsteroidal anti-inflammatory decreasing in dose over 3 to 5 days (e.g., flunixin meglumine 1.1 mg/kg twice daily for 2 days, 0.5 mg/kg twice daily for 1 to 2 days, and 0.5 mg/kg once daily for 1 to 2 days), along with a topical steroid twice daily (assuming no contraindication for its use), and a single dose of topical 1% atropine (again, assuming no contraindication for its use), with a plan to recheck in approximately 5 to 7 days to ensure that uveitis has improved or resolved prior to discontinuing therapy. A Grade 3 horse might receive a longer course of a systemic nonsteroidal anti-inflammatory (e.g., flunixin meglumine 1.1 mg/kg twice



Fig. 11. Grade 4, severe active signs of uveitis including uncontrolled glaucoma with Haab's striae, and chronic changes including dyscoria and posterior synechia.

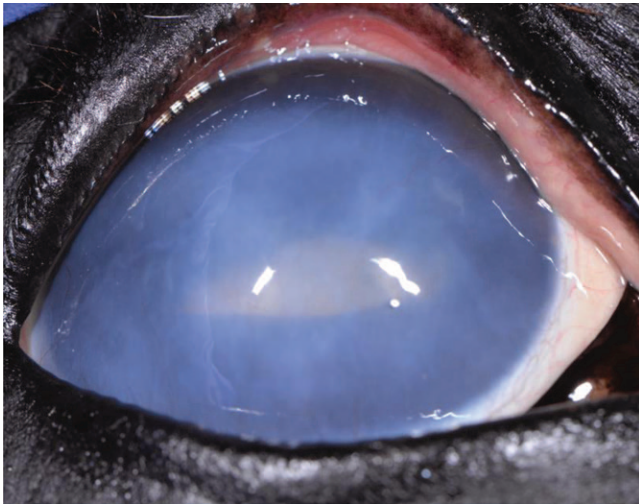


Fig. 12. Grade 4, severe active signs of uveitis including uncontrolled glaucoma with severe corneal edema, and chronic changes including hypermature cataract and posterior lens luxation.

daily for 3 to 5 days, 0.5 mg/kg twice daily for 3 to 5 days, 0.25 mg/kg twice daily for 3 to 5 days, and 0.25 mg/kg once daily for 3 to 5 days), along with a topical steroid 3 to 4 times daily for 1 week, then twice daily for 1 week, and once daily until uveitis resolves, as well as topical 1% atropine once daily for 1 week, then three times weekly for 1 to 2 weeks, and once weekly for 1 to 2 weeks, with a plan to recheck initially after approximately 3 to 5 days to ensure that uveitis has improved, and then weekly to ensure that uveitis has resolved prior to discontinuing therapy. A Grade 4 horse may be treated similarly to a Grade 3 horse but for longer duration and more aggressively, considering the use of systemic corti-

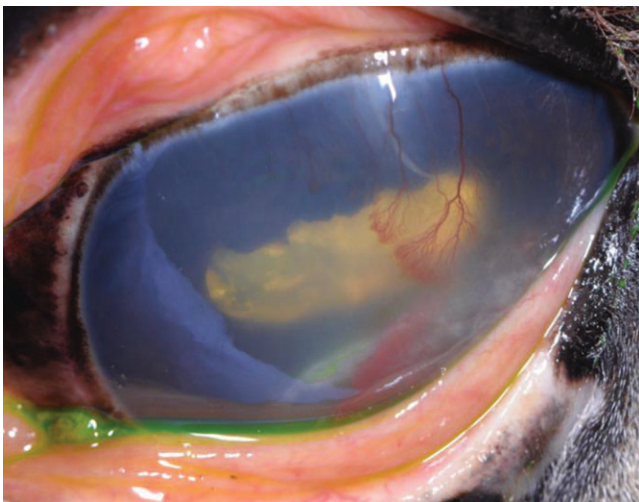


Fig. 13. Grade 4, severe active signs of uveitis including corneal edema, corneal vascularization, and aqueous flare (difficult to see in this photograph) and chronic changes including hypermature cataract and posterior synechia.



Fig. 14. Grade 5, phthisis bulbi. This eye is permanently blind and may be painful. Secondary changes including conjunctivitis associated with accumulation of debris and mucopurulent ocular discharge between eyelids and small globe. Enucleation is warranted if a phthisical eye is painful.

costeroids (if not contraindicated) initially, instead of systemic nonsteroidal anti-inflammatories. Recheck examinations on these patients should occur every few days, with hospitalization if treatment frequency or recheck frequency cannot be accommodated at the home barn. In addition, therapy for treatable secondary complications must be instituted (e.g., timolol/dorzolamide for glaucoma). A Grade 5 horse may need treatment if there is detectable pain associated with phthisis bulbi, and enucleation may be warranted.

A discussion of surgical therapy for uveitis is beyond the scope of this paper, however it is important to recognize that surgical therapies exist, including placement of a cyclosporine implant in the suprachor-



Fig. 15. Grade 5, advanced phthisis bulbi with profound elevation of the third eyelid.

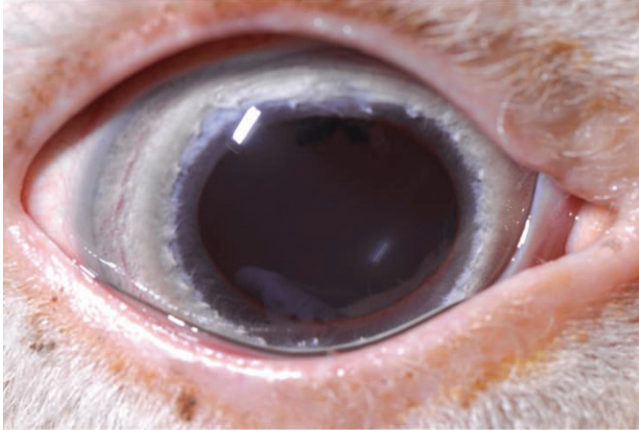


Fig. 16. Blue iris in a normal eye.

roidal space, to reduce the frequency and severity of flareups of uveitis, and surgeries for secondary disease such as cataracts and glaucoma.

Regarding the treatment of ERU that has been classified as anterior, insidious and posterior, it is really disease severity that should dictate the frequency and duration of treatment; however, special note should be taken of three considerations. First, insidious ERU by its very nature implies ongoing inflammation, and therefore horses with insidious ERU would likely best be served by continuous therapy to minimize flare-ups. The decision to institute continuous therapy must be weighed with the anticipated level of owner compliance with recheck examination recommendations, as long-term topical and/or systemic immunosuppressive or anti-inflammatory therapy carries a risk of a variety of complications. Second, uveitis in horses with posterior ERU may be difficult to detect given the posterior location of the signs, and therefore therapy should

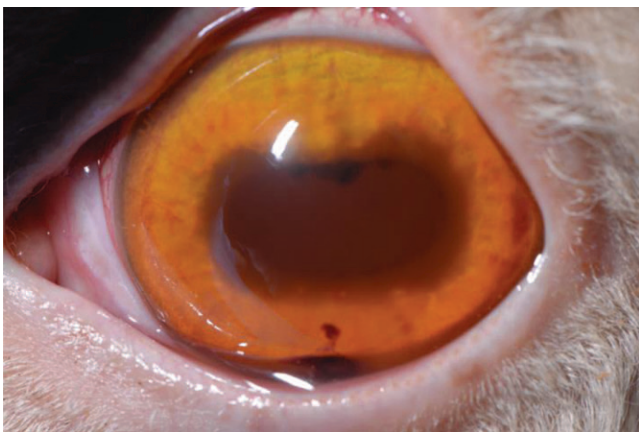


Fig. 17. Opposite eye of the horse pictured in Fig. 16, demonstrating serum staining of blue iris leading to yellowish iris discoloration, and rubeosis iridis (pronounced iris vascularization). This iris returned to its normal blue color when uveitis resolved.

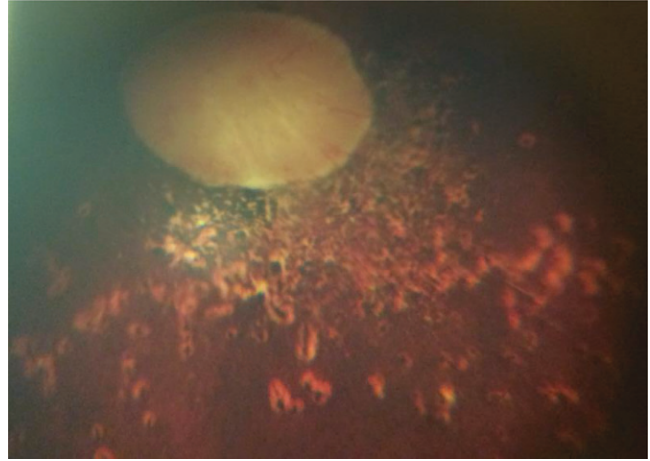


Fig. 18. Numerous chorioretinal scars sometimes called “bullet-hole” lesions inferior to the optic disc.

be discontinued only after careful examination of the posterior, as well as anterior, segments confirms that uveitis has resolved. Finally, because posterior ERU occurs in the posterior segment of the eye, topical therapy with ophthalmic medications are unlikely to reach the back of the eye, and therefore systemic therapy is important.

3. Results

There is really no way to demonstrate that an ERU diagnostic scheme “works” as there is no independent way to confirm the diagnosis, and there is no cure for the disease. The proposed diagnostic scheme and treatment recommendations are simply proposals to encourage necessary and sufficient information be included from the history, in the ocular examination, and in treatment and follow-up recommendations.

4. Discussion

The challenges associated with diagnosing and treating horses with ERU include uncertainty in the history, ambiguity in the diagnosis, noncompliance or misunderstanding treatment recommendations, and the client simply giving up on the horse. By having a well-defined protocol for history, ocular examination, diagnosis, treatment, and follow-up plan, these challenges can be minimized. In addition, clear communication with owners about diagnosis, prognosis, and treatment options is very important.

First, it is critical to ensure that owners understand that ERU is a lifelong inflammatory disease for which there is no cure. Systemic conditions that may limit the use of traditional therapy include right dorsal colitis, renal insufficiency, and laminitis, all of which limit the ability to use systemic anti-inflammatory drugs to treat episodes of uveitis (the first two limiting the use of systemic NSAIDs and the last limiting the use of systemic corticosteroids).

Second, owners may not be interested in committing to lifelong treatment if the horse's intended use is limited by ERU, or may not be able to manage chronic or recurrent treatment of fractious horses. In these cases, a more permanent solution (e.g., enucleation of a chronically blind and painful eye) may avoid unnecessary pain for the horse and expense for the owner. Sometimes, secondary ocular disease such as corneal ulceration develops, and owners do not always clearly understand that such secondary disease is temporary rather than also chronic and recurrent.

Finally, financial constraints may prevent owners from being able to commit to treatment of chronic or recurrent inflammatory ocular disease, and thus, again, a more permanent solution may be warranted. Sometimes owners do not have a realistic idea of the necessary duration of treatment and "give up" on an eye that could be saved, simply because the time or cost involved in therapy was more than they realized. In other cases, owners are reluctant to pursue a definitive solution like enucleation for a blind painful eye because they do not realize that horses can have an excellent quality of life, and even continue to perform in their intended discipline, with only one eye.¹³

This paper provides a detailed guide for clinical assessment of horses that present with active signs of intraocular inflammation, and horses whose owners know of or suspect previous intraocular inflammation. However, in the course of performing routine physical examinations practitioners often identify horses with one or more signs of inactive uveitis in one or both eyes that no one has previously noted. A history may not be available, and the owner may be unaware that any ocular problem exists. As the historical component of the algorithm described in this paper is missing, the clinician may be uncertain of the diagnosis. These cases offer the opportunity to inform the owner as to the possibility of an ERU diagnosis. The clinician should educate the owner about clinical signs that might indicate onset of an episode of active uveitis and emphasize the need for prompt veterinary evaluation if any such signs occur. In the absence of acute signs, frequent ophthalmic evaluation should be scheduled to look for progression of disease. Cases of ERU will thus be confirmed by a later occurrence of an active flare, or the progression of intraocular inflammation or inactive signs over time. Treatment decisions can thus be made according to the parameters described previously.

We know that ERU carries a guarded visual prognosis, but we do not currently know which cases are going to become blind, or how soon severe progression will occur. This scheme is one step in attempting to more specifically characterize disease severity, which can provide information about visual prognosis and ultimately help guide therapy.

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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Risk Factors for Mortality and Post-Operative Complications Following Umbilical Remnant Resection in 82 Foals

Laia Reig, BVM*; Stephen Rakem Were, PhD; and James A. Brown, BVSc, MS, DACT, DACVS

Surgical excision of infected and/or patent umbilical remnants in foals has an overall good prognosis. Preoperative septic joints and development of new septic joints following surgery significantly decreased survival. Authors' addresses: Marion DuPont Scott Equine Medical Center, Leesburg, VA 20176 (Reig, Brown); and Study Design & Statistical Analysis Lab Supervisor, Virginia-Maryland Regional College of Veterinary Medicine, 205 Duck Pond Drive, Room 249, Blacksburg, VA 24061 (Rakem Were); e-mail: lreigcodina@gmail.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Umbilical remnant infections and patent urachus are an important cause of morbidity in foals. Risk factors for post-operative complications or mortality after surgical removal are poorly described.

2. Materials and Methods

Retrospective analysis of foals undergoing umbilical resection due to patent and/or infected umbilical remnants at the Marion duPont Scott Equine Medical Center from 2004 to 2016 were included in the study. Associations between outcome and risk factors were assessed using bivariable and multivariable analyses.

3. Results

Eighty-two foals underwent umbilical remnant resection of which 73 (89%) survived to discharge. The urachus was the most commonly affected struc-

ture being patent and/or infected in 84.1% of cases. Concurrent conditions were present in 60.6% of foals prior to surgery, with diarrhea and septic joints being most common. The presence of preoperative septic joints resulted in significantly decreased survival ($P = .004$). Development of a new septic joint after surgery was the only complication associated with increased mortality ($P = .0041$). Longer anesthesia time was associated with increased risk for postoperative complications ($P = .0015$).

Acknowledgments

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Conflict of Interest

The Authors have no conflicts of interest.

Research Abstract—for more information, contact the corresponding author

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Clinical Findings and Management of 153 Horses with Large Colon Sand Accumulations

Isabelle Kilcoyne, MVB, DACVS*; Julie E. Dechant, DVM, MS, DACVS, DACVECC; Sharon J. Spier, DVM, PhD, DACVIM; Mathieu Spriet, DVM, MS, DACVR, DECVDI; and Jorge E. Nieto, MVZ, PhD, DACVS, DACVSMR

The sheer quantity of sand is not a factor when determining surgical intervention. Attention should be paid to the presence of increased gas accumulation on rectal or radiographic examination. Authors' addresses: William R. Pritchard Veterinary Medical Teaching Hospital (Kilcoyne), Department of Medicine and Epidemiology (Spier), and Department of Surgical and Radiological Sciences (Dechant, Spriet, Nieto), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; e-mail: isabellekilcoyne@hotmail.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

To determine whether objective radiographic measurement of sand is associated with surgical intervention in the management of large colon sand accumulations. To compare short- and long-term outcome and complications associated with medical and surgical management of these horses.

2. Materials and Methods

Medical records and abdominal radiographs of 153 horses that presented for colic to the William R. Pritchard Veterinary Medical Teaching Hospital between 2004 and 2014 were reviewed. Severity of sand accumulation was objectively measured by tracing a region of interest using a commercial software program. Evaluated factors included breed, weight, amount of sand, presence of diarrhea at presentation, treatment, and the development of complications.

3. Results

Records from 153 horses were reviewed. Mean cross-sectional area of sand accumulation was 692.9 cm² (median, 658.7cm²; range, 84.6 to 1780.7cm²). Increased accumulation of gas on radiographs and abnormal transrectal examination findings were significantly associated with an increased likelihood of requiring surgery. The most common encountered complication was the development of diarrhea (20.3%) with only four (2.6%) horses positive for *Salmonella* spp. Horses had a favorable prognosis with 94.8% of horses treated medically and 94.7% of those treated surgically surviving to discharge.

4. Discussion

Increased accumulation of gas on radiographs and transrectal palpation of impaction or intestinal gas distension increases the likelihood of surgery. A

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good prognosis for both medical and surgical management can be offered.

Acknowledgments

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Conflict of Interest

The Authors have no conflicts of interest.

A Comparison of the Effects of Topical Application of UMF 20 and UMF 5 Manuka Honey with a Generic Multi-Floral Honey on Wound Healing Variables in an Uncontaminated, Surgical, Equine Distal Limb Wound Model

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Unique Manuka Factor-20 Manuka honey improves healing of equine distal limb wounds compared with generic honey and saline. Authors' addresses: Research and Clinical Trials Unit, University Veterinary Teaching Hospital Camden, University of Sydney, 410 Werombi Road, Camden, New South Wales 2570, Australia (Tsang, A. Dart, Sole-Guitart, C. Dart, Jeffcott); and School of Veterinary Science, Faculty of Science, University of Queensland, Main Drive & Outer Ring Road, Gatton, Queensland 4343, Australia (Perkins); e-mail: albert.tsang@sydney.edu.au. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Wounds on the equine distal limb are common, often involving extensive tissue avulsion and contamination precluding primary closure. Honey from the Manuka bush (*Leptospermum scoparium*) is known to have antibacterial and immunomodulatory effects. Recent studies have shown beneficial effects of UMF20 Manuka honey (UMF20) on healing of equine distal limb wounds.

2. Materials and Methods

Two full-thickness skin wounds (2.5 × 2.5 cm) were created bilaterally on the metatarsii of eight horses. Wounds were assigned one of four treatments:

UMF20 Manuka honey (UMF20), UMF5 Manuka honey (UMF5), generic, multi-floral honey (GH), and saline control. Bandages were changed daily for 12 days, after which treatment was stopped and bandages removed. Wound area was measured on day 1, then weekly until day 42. Overall wound healing rate (cm²/day) and time to complete healing was recorded.

3. Results and Discussion

On day 1, mean area of all wounds was not different. During the 42 days following wound creation, mean wound area only differed on day 21; UMF20-treated wounds were smaller than UMF5-treated wounds ($P = .031$). All other comparisons were not differ-

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ent. The overall healing rate was not different between treatment groups. Wounds treated with UMF20 healed faster (90.78 days) than GH (100.30 days; $P = .02$) and controls (101.36 days; $P = .01$). Treatment of wounds with UMF20 Manuka honey reduced overall wound healing time compared with wounds treated with GH and saline controls.

Acknowledgments*Declaration of Ethics*

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Conflict of Interest

The Authors have no conflicts of interest.

How to Prepare and Store Equine Amnion for Use as a Biological Wound Dressing

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1. Introduction

Deep and chronic wounds in horses, particularly of the distal limbs, are a major challenge to treat and manage. Biological wound dressings, such as equine amnion, offer many advantages in the management of these wounds, including promotion of wound contraction and epithelialization without increasing the risk of exuberant granulation tissue formation.¹ Amnion is the innermost layer of fetal membranes and is composed of a single layer of cuboidal epithelial cells, a basement membrane, and a connective tissue layer that is markedly thicker in the horse compared with other species (Fig. 1).² Amnion contains numerous factors that promote growth and wound healing, including epidermal growth factor, vascular endothelial growth factor, and transforming growth factor beta, among others.³ It has been found to enhance neovascularization, modulate production of inflammatory mediators, and recruit stem cells to wound beds.^{4,5}

The use of amnion as a biologic dressing for the treatment of nonhealing wounds and as a surface dressing for burns or over skin grafts has been reported in the human literature starting in the early 1900s.⁶⁻⁹ In the equine literature, the use of am-

nion as a wound dressing has been investigated under experimental conditions and reported in a limited number of clinical cases.¹⁰ In experimentally created wounds (2.5 cm × 2.5 cm) over the dorsal aspect of the cannon bone in horses and ponies with and without pinch grafting, respectively, those treated with amnion healed faster and required less intervention for exuberant granulation tissue than did control wounds covered with a non-adherent dressing.^{11,12} The use of equine amnion to treat full-thickness experimental skin wounds in dogs has also been reported to increase rates of contraction and epithelialization and decrease healing time compared with wounds treated with alternative dressings.¹³

A commercial equine amnion product, available as a shelf-stable sheet and as a liquid, has recently come on the market.^a However, during foaling season, fresh amnion is readily available to many practitioners and can be processed and stored for later use. A single placenta can yield dozens of amnion dressings that are easily trimmed to an appropriate size for a wide variety of wounds. There are two published tissue-preparation protocols, one using dilute chlorhexidine (first reported by Ramsey et al¹³) and the other using iodine and acetic acid (first reported by Bigbie et al¹⁰).

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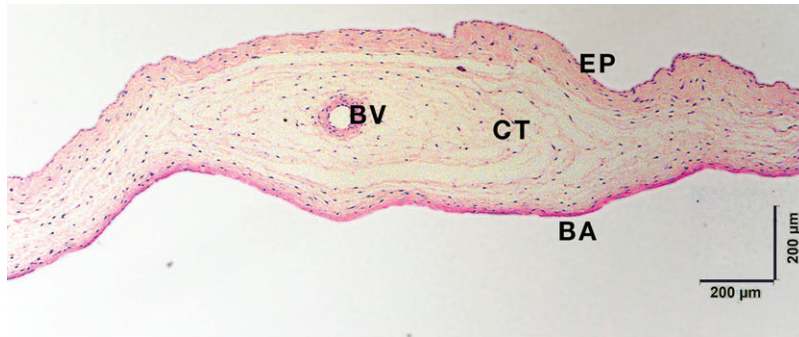


Fig. 1. Histologic image of normal equine amnion. EP, epithelium; CT, connective tissue; BV, blood vessel; BA, basement membrane. Hematoxylin & eosin (H&E) stain, 40× magnification. Image courtesy of Dr. Patrick Roady.

2. Materials and Methods

Recommended Materials

- Two to four buckets or pans large enough to hold amnion (we have found that large dish pans work well). Sterile impervious drape. Towel.
- Mayo or Metzenbaum scissors, sterile saline, 1000-mL bottles, room-temperature 2% chlorhexidine or 7.2% povidone-iodine (must not contain isopropyl alcohol) and 5% acetic acid.
- Storage containers (will vary based on size and storage conditions, but can use saline bottles, sterile specimen cups, 50-mL conical tubes, etc.)

Amnion Collection and Initial Preparation

Fresh amnion should be collected and processing begun as soon as possible after foaling (preferably within 1 hour). Only amnion that is grossly normal in appearance should be used. If there must be a delay in processing (up to 12 hours), the amnion should be refrigerated in a clean plastic bag or rectal sleeve. Gross debris (bedding, dirt, hair, blood, etc.) should be removed by rinsing and gentle agitation in cool tap water (Fig. 2). We have found that using warm/hot water increases tissue edema during rinsing. If there are areas of the amnion with

ground-in dirt or debris, these can be cut out and discarded.

The volumes in the following protocols are sufficient to process amnion from an average-sized horse placenta. However, they can be scaled up or down as needed.

Processing—Chlorhexidine Protocol

1. Add 10 mL 2% chlorhexidine to 400 mL sterile saline (room temperature) in a pan (or bucket) to create a 0.05% solution.
2. Add amnion, allow to sit for 1 hour at room temperature, agitating periodically (Fig. 3).
3. Sequentially rinse amnion in 0.05% chlorhexidine and sterile saline, three times; having two pans (or buckets) available, one for the chlorhexidine solution and one for the saline, facilitates this process. Each rinse should take 2–3 minutes, with gentle agitation to facilitate the removal of any remaining debris.
4. After final saline rinse, spread amnion out on a sterile impervious drape (towel underneath facilitates cleanup) and cut to desired size for future use.
5. Create a 0.025% storage solution by adding 1.25 mL 2% chlorhexidine per 100 mL sterile saline. If planning to store in the refrigera-

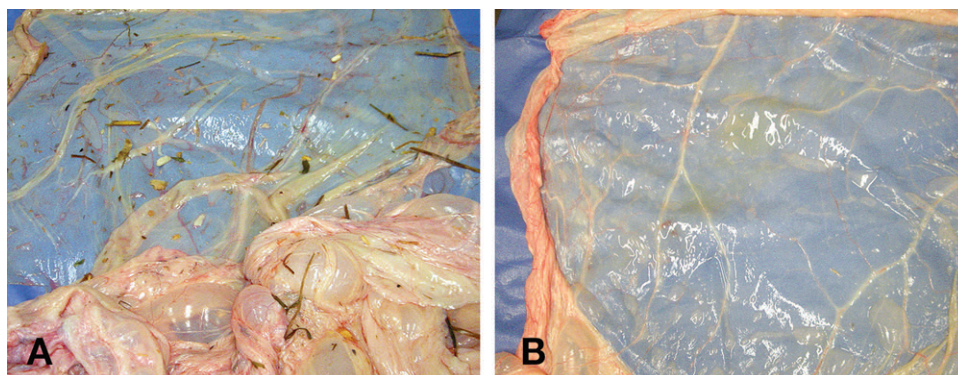


Fig. 2. Equine amnion before (A) and after (B) rinsing for removal of gross debris.

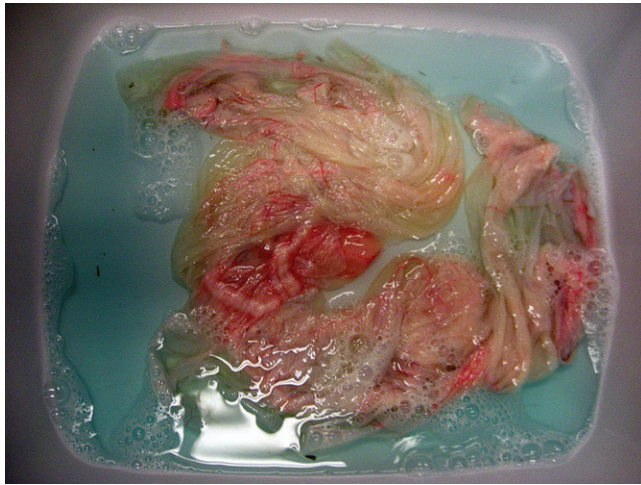


Fig. 3. Equine amnion in 0.05% chlorhexidine solution. A dish pan is being used in this case.

tor, use of a 1000-mL saline bottle is recommended; in this case, add 6.25 mL 2% chlorhexidine to 500 mL sterile saline in the bottle. Each bottle will easily hold approximately a third to half of the amnion from a normal-sized placenta (Fig. 4).

Processing—Iodine/Acetic Acid Protocol

1. Add 250 mL 7.2% povidone iodine to 600 mL sterile saline (room temperature) to create a 2% solution in a 1000-mL saline bottle. The iodine solution used for this step must not contain isopropyl alcohol or the tissue will become dehydrated and not us-



Fig. 4. Processed equine amnion in 0.025% chlorhexidine (left) or 0.25% acetic acid (right) ready for refrigeration until use. The bluish hue of the chlorhexidine-processed tissue and the yellow color of the iodine-processed tissue will remain even after prolonged storage.



Fig. 5. Equine amnion in 2% povidone-iodine, ready for 24-hour refrigeration period.

- able. Each bottle prepared in this manner will hold a third to half of the amnion from a normal-sized placenta; there may be some overflow.
2. Add amnion to the bottle, agitate gently until completely submerged, and refrigerate at 4°C for 24 hours (Fig. 5).
 3. Create a 0.25% rinse and storage solution by adding 20 mL 5% acetic acid to 400 mL sterile saline in a pan (or bucket).
 4. Rinse the amnion three times in sterile saline, then once in the acetic acid solution. As mentioned previously, having two pans (or buckets) available to transfer the amnion between rinses facilitates this process. Each rinse should take 2–3 minutes, with gentle agitation to facilitate the removal of any remaining debris.
 5. After final saline rinse, spread amnion out on a sterile impervious drape (towel underneath facilitates cleanup) and cut to desired size for future use (Fig. 6).
 6. Store samples in 0.25% acetic acid (as described in step 3; 5 mL 5% acetic acid per 100 mL sterile saline). If planning to store in the refrigerator, use of a 1000-mL saline bottle is recommended; in this case, add 25 mL 5% acetic acid to 500 mL sterile saline in the bottle. Each bottle will easily hold approximately a third to half of the amnion from a normal sized placenta (Fig. 4).

Storage

Amnion may be stored in temperature-appropriate containers in the refrigerator (4°C) or freezer



Fig. 6. Iodine-processed pieces cut into 5 cm × 5 cm squares for future use, prior to refrigeration or freezing.

(−20°C or −80°C). In the initial descriptions of these processing protocols in the literature, refrigerated samples stored in either dilute chlorhexidine or dilute acetic acid were free of bacterial contamination when tested at 6 months and 5 months after processing, respectively.^{10,13} When using thawed frozen dressings, Bigbie et al¹¹ reported discarding any tissue that remained after 3 weeks. Storage containers should be labeled with the processing date.

3. Results

Both amnion-processing protocols can be performed with minimal setup and no specialized equipment. Both are effective at eliminating bacterial contamination from equine amnion and result in dressings that can be stored for prolonged periods of time.^{10,13} Thus, selection of protocol may be largely dependent on personal preference. However, we have found some minor differences between the protocols that may sway a practitioner one way or another. For example, samples treated with chlorhexidine seem to be more prone to becoming edematous and separating (the vascular layer from the avascular layer) during processing. We have found markedly edematous tissue more difficult to use clinically and typically choose to discard it. Although the use of room temperature, rather than warm saline for rinses helps to address this issue, it does not eliminate it completely. This does not seem to be a problem with tissue processed with iodine/acetic acid, even when the tissue is from the same horse. In contrast, there is routinely tissue debris left in the saline rinses for the iodine/acetic acid protocol, suggesting that the 24-hour refrigeration in iodine may result in some level of damage to the surface layers of the tissue. We have not found this to be a problem clinically when using amnion processed in this way, but further investigation (i.e., histopathology) may be warranted. The iodine also stains the amnion a yellow color with variable intensity, which may be cosmetically undesirable (Fig. 6) although it should not affect efficacy.

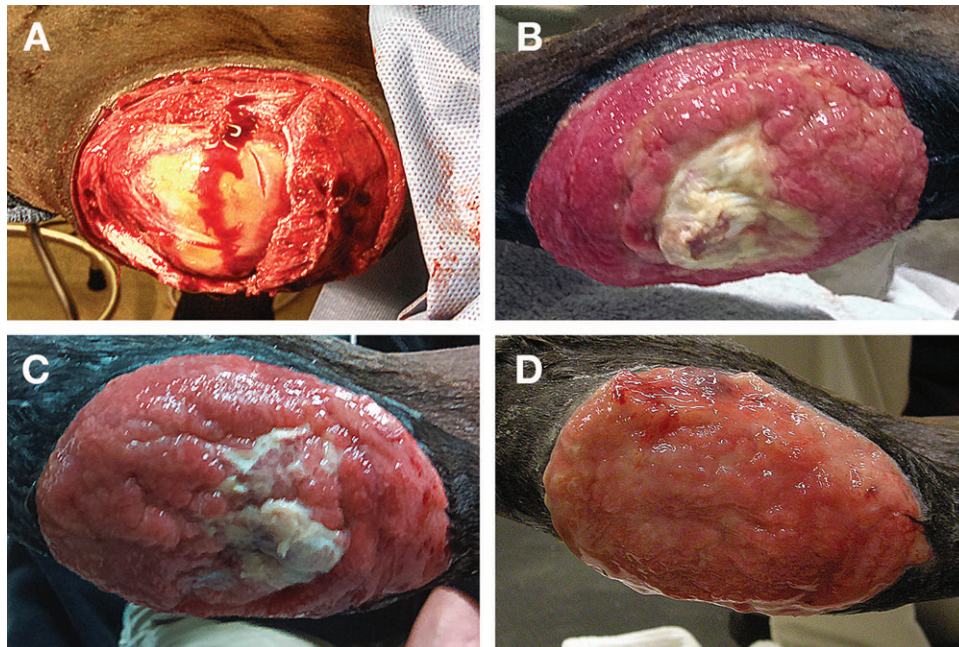


Fig. 7. Progression of healing of a large wound over the point of the hock in a foal treated with equine amnion. A, Day 0, after surgical debridement; (B) day 12; (C) day 21; (D) day 33.

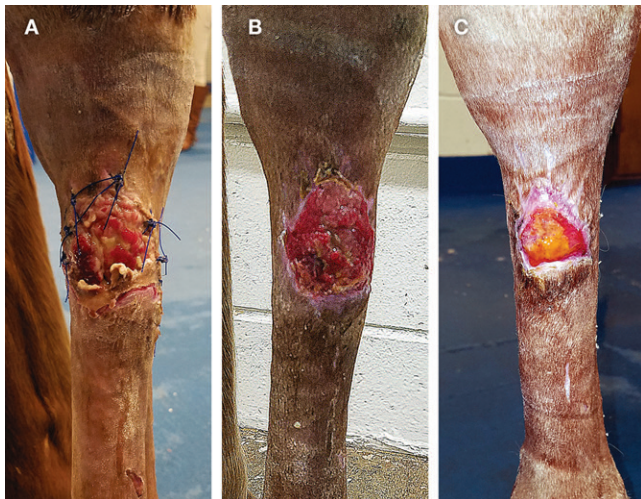


Fig. 8. Progression of healing of a wound on the dorsal aspect of the cannon bone. A, day of dehiscence, 12 days after primary surgical repair; (B) day 13 of amnion treatment; (C) day 27. Granulation tissue required trimming once.

4. Discussion

The author's practice routinely uses equine amnion as a wound dressing in a variety of clinical cases, including chronic/nonhealing wounds of the distal limb (Fig. 7), wound dehiscence (Fig. 8), and cast sores (Fig. 9). We have used both of the processing protocols described above, and prefer to refrigerate the amnion dressings in their respective storage solutions in 1000-mL saline bottles until use, as shown in Fig. 4. We have also experimentally stored amnion at both -20°C and -80°C . Subjectively, tissue stored at -20°C has a more "wrinkled" appearance immediately after being thawed than tissue that has been refrigerated or stored at -80°C . This makes the tissue somewhat more difficult to manipulate; based on this experience and previous reports,^{10,11} thawing tissue in the refrigerator for 24 hours before use would be recommended.

Amnion dressings are quite economical; following either protocol, the cost to process the amnion from one placenta is approximately \$25–30, and this tis-



Fig. 9. Progression of healing of cast sores on the palmar aspect of the left front fetlock of a horse with a flexor tendon laceration. Day 0, before (A) and after (B) placement of an amnion dressing; (C) day 17.

sue can subsequently be used for dozens of dressings (depending on wound size), making the cost per bandage change less than \$1. By comparison, commercially available, nonbiologic, "active" dressings intended to promote wound healing range in price from \$2.50–15.00 or more per bandage change. Although amnion can be glued to the skin and allowed to desiccate,¹ we typically use it underneath a bandage, changing the dressing every 3–7 days depending on the type of bandage and the characteristics of the wound. Given the lengthy healing time for many wounds healing by second intention, it is not difficult to imagine that the cost differential can be substantial.

We have found equine amnion to be a valuable addition to our toolkit for managing wounds healing by second intention. The protocols described here are easy to use and readily adaptable to a wide range of practice situations.

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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^aEquusCell StemWrap and EquusCell StemWrap+, AniCell BioTech, Chandler, AZ 85226.

Non-Weight-Bearing Ultrasound Examination for Diagnosis of Longitudinal Fiber Disruption (Split) in Equine Suspensory Ligament Branches

Natasha M. Werpy, DVM, DACVR*†; Leah Griffith, DVM†; and Kristina Chapman, DVM

Complete ultrasound examination of the suspensory ligament requires weight-bearing (WB) and non-weight-bearing (NWB) approaches. Certain abnormalities, such as longitudinal fiber disruption (split) in the suspensory ligament branches may only be evident when imaged NWB. Authors' addresses: Equine Diagnostic Imaging, Inc., 14313 SW 79th Street, Archer, FL 32618 (Werpy, Griffith); and Bell Equine Veterinary Clinic, 104 Butchers Lane, Mereworth, Maidstone ME18 5GS, United Kingdom (Chapman); e-mail: equinedxim@yahoo.com. *Corresponding author; †presenting authors. © 2017 AAEP.

1. Introduction

Suspensory ligament branch (SLB) injury is often diagnosed with ultrasound. To provide the most accurate information, ultrasound examinations would ideally correlate with MRI findings. In certain cases, there is discrepancy between MRI findings and ultrasound imaging characteristics. It is proposed that weight bearing (WB) during ultrasound examination contributes to obscuring certain types of abnormalities, specifically SLB splits.

2. Methods

Ultrasound examination was performed on SLBs with the limbs in WB and nonweight-bearing (NWB) positions. Splits in the SLBs were defined as linear regions of decreased echogenicity when imaged with the limb in a WB position that increased in size and became anechoic with the limb in a NWB position, and were categorized as partial or complete.

3. Results

Ultrasound examination was performed NWB on 58 SLBs, with 13 partial and 12 complete splits identified. Recheck ultrasound examinations performed in four horses up to 10 months following the initial examination demonstrated persistence of the split in one horse, partial resolution in two horses and complete resolution in one horse.

4. Discussion

Ultrasound examination using the NWB approach is valuable for increasing the conspicuity of lesions that may decrease in size when WB. This technique provides a more accurate representation of the lesion severity and allows monitoring over time. A longitudinal study is necessary to determine the clinical relevance of NWB findings.

Research Abstract—for more information, contact the corresponding author

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Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.

Comparison of Ultrasound and MRI for Detection of Soft Tissue Injuries in the Palmar Aspect of the Equine Foot

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and David D. Frisbie, DVM, MS, PhD, DACVS, DACVSMR

Ultrasound is a sensitive screening tool for evaluation of tears of the deep digital flexor at the proximal recess of the navicular bursa but risks over and underestimating soft tissue changes when compared with MRI. Authors' addresses: Department of Environmental and Radiological Health Sciences, Veterinary Teaching Hospital (Shields, Barrett); and Orthopaedic Research Center, Department of Clinical Sciences, (Frisbie) Colorado State University, Fort Collins, CO 80523; e-mail: barrettdvm@gmail.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Magnetic resonance imaging (MRI) allows for the most complete diagnostic imaging of the equine foot, but ultrasound is more readily available and less expensive. This study compares ultrasound to MRI for diagnosis of injuries visible with ultrasound within the palmar foot, including the deep digital flexor tendon (DDFT), collateral sesamoidean ligament (CSL), and navicular bursa (NB).

2. Materials and Methods

MRI of the foot and ultrasound of the foot between the heel bulbs prior to MRI analysis were acquired prospectively in clinical patients.

3. Results

A total of 70 ultrasound and MRI exams of 45 horses were included. Ultrasound had good sensitivity (85%), moderate specificity (60%), and accuracy of 70% for evaluating dorsal tearing of the DDFT. Accuracy was lower for NB effusion (67%), NB proliferation (61%),

and CSL enlargement (61%). Tearing of the DDFT distal to the navicular bone was identified with MRI in 27 limbs, 20 of which also had dorsal damage proximal to the navicular bone identified with ultrasound.

4. Discussion

Ultrasound evaluation remains a useful screening tool, particularly for assessment of DDFT tearing proximal to the navicular bone, but risks underdiagnosing pathology to the navicular bursa and CSL. Clinically significant concurrent damage to the distal DDFT and other osseous and soft tissues in the hoof capsule are unlikely to be identified without MRI.

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.

Research Abstract—for more information, contact the corresponding author

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How to Perform an Ultrasound-Guided Paratendinous Injection of the Equine Navicular Bursa: 112 Cases

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Ultrasound-guided paratendinous injection of the navicular bursa is a safe injection technique that is an alternative to the commonly used transtendinous injection techniques. Authors' addresses: EquiSound, Equine Medical Centre, Ursel, Belgium (Hoegaerts, Hauspie); and Department of Environmental and Radiological Health Science, Colorado State University, Fort Collins, CO 80523 (Barrett); e-mail: mhoegaerts@me.com *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Injection of the navicular bursa (NB) is a widely used technique to diagnose and treat horses with navicular syndrome. Multiple techniques are described for needle entry into the NB, either under radiographic or ultrasonographic control.^{1,2} Many of these use a (para)sagittal approach with puncture of the deep digital flexor tendon (DDFT), which remains a concern for many clinicians because it may produce adhesions and/or tendon degeneration. Recently, lateral approaches for centesis of the NB have been described avoiding puncture of the DDFT, either under radiographic or ultrasonographic guidance.³⁻⁵ The reported ultrasonographic studies used cadaver limbs.

The equine foot has a complex anatomy in which the navicular bone acts as a trochlea where the DDFT changes its angle in the foot. The NB is a synovial cavity between the navicular bone and the DDFT, facilitating sliding of the DDFT. The

NB has a lateral and medial proximal collateral recess (Fig. 1), which can be imaged with ultrasound.^{6,7} As anatomical landmarks of the NB depend on the conformation of the foot, using imaging to guide the injection is recommended. Based on the visibility of the NB with ultrasound, we developed the following technique for use in the standing horse.

The purpose of this article is to describe an ultrasound-guided tendon-sparing lateral approach for centesis of the NB that can be used in a clinical setting, presenting it as a valid alternative for the more commonly used (para)sagittal approaches that puncture the DDFT.

2. Materials and Methods

The limb is clipped at the level of the lateral heelbulb from the level of the coronary band to mid pastern. The hoof and fetlock are covered with bandages and the lateral heelbulb is scrubbed and prepared aseptically. In cases where diagnostic an-

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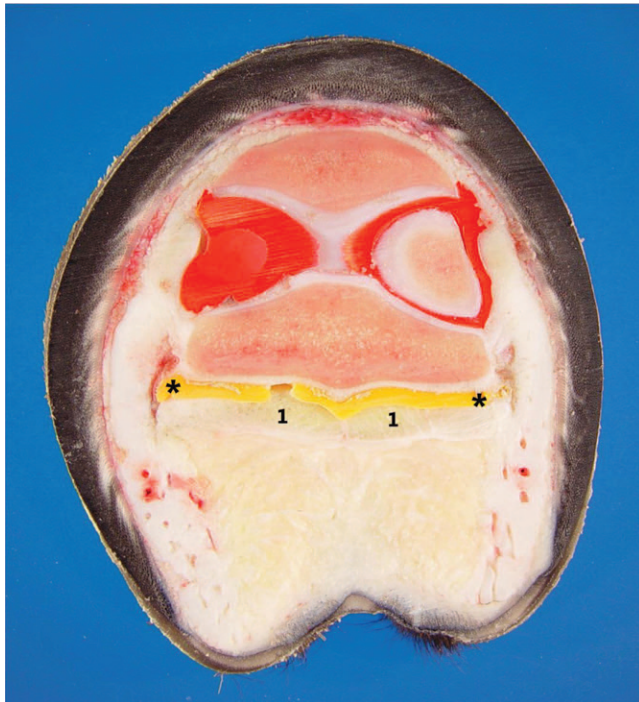


Fig. 1. Anatomical specimen of the distal foot of a horse. The NB is filled with a yellow dye. The asterisks are highlighting the lateral and medial collateral recesses. The '1' represents the DDFT.

esthesia of the bursa is desired, the horse is not sedated (or only mildly) and no regional block or local desensitization of the skin is performed. In cases where treatment of the NB is performed, the horse is sedated and a local block or desensitization of the skin is performed.

The leg is placed in a weight-bearing stance with the hoof positioned more caudally than the contralateral limb to obtain hyperextension of the coffin joint and gain better access to the palmar/plantar aspect of the pastern region, similar to the positioning for a skyline radiograph of the navicular bone (Fig. 2). A microconvex probe, prepared aseptically with alcohol and covered in a sterile glove, is positioned between the heelbulbs and a transverse view of the lateral lobe of the DDFT and the lateral recess of the NB is obtained (Fig. 3). A spinal needle (20–21 G, 1.5 in.) is inserted lateral to the transducer and axial to the lateral ungular cartilage, positioned in the plane of the ultrasound beam toward the lateral recess of the bursa (Fig. 2). The bevel of the needle has to be pointed axially to allow the needle to drive toward the sagittal plane when advancing toward the NB. When the tip of the needle is positioned inside the synovial cavity, the stylette of the spinal needle is removed and a sterile injection can be performed into the NB (Fig. 3). The injection is monitored ultrasonographically to ensure correct needle placement. In the first 10 cases, iodinated contrast material was injected to assure the correct placement



Fig. 2. Illustration of the caudal position of the foot of the horse during imaging and centesis. The needle is placed inside the beam of the ultrasound probe.

of the anesthetic solution in the NB by means of radiography (Fig. 4); this is recommended when first using this technique.

3. Results

During a period of 5 years, 123 feet were injected using this technique.

In 11 cases ultrasound-guided injection of the NB was not possible because there was no fluid detected in the NB or the heelbulbs were too narrow to obtain good image quality. In the remaining feet, a small ($n = 33$), moderate ($n = 41$) to large ($n = 38$) amount of fluid was present in the lateral recess of the NB and ultrasound confirmed the injection was within the NB.

Once the needle penetrated the skin, most horses tolerated further needle positioning well. Reduced resistance was noticed when the needle penetrated the wall of the NB. If a moderate to large amount of fluid was present in the NB, synovial fluid leaked from the needle after removal of the stylette ($n = 79$; Fig. 2). Injection of 2 mL was easy to perform without any resistance. To prevent extra-synovial leakage, only a small amount of fluid (1–2 mL) was injected. Lifting the limb from the ground immediately after injection is advised to reduce intrasynovial pressure and to prevent leakage.

Correct intrasynovial injection of the NB was confirmed by visualization of the distention of the NB during injection, visualization of injected microbubbles and/or aspiration of the injected solution through the needle. In the first 10 cases, 1 mL of contrast agent was added to the anesthetic solution. Radiographic evaluation after injection demonstrated in all 10 cases a distinct filling of the NB with contrast agent. In three cases a small amount of contrast material leaked from the needle tract.

No severe complications were experienced (No infectious bursitis, no pain after injection). Seven horses moved their foot during the procedure. In

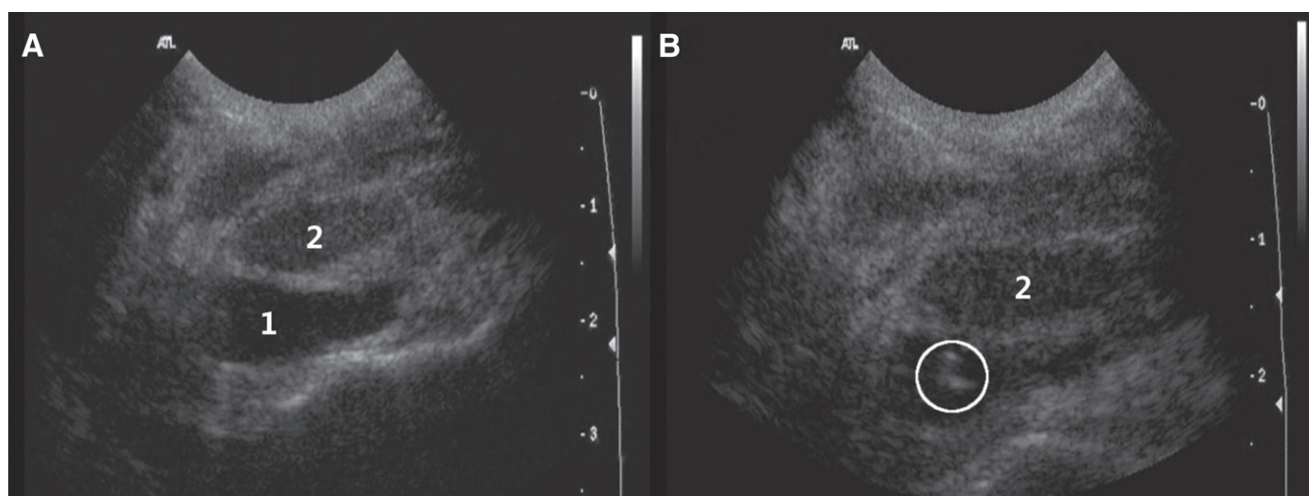


Fig. 3. A, Transverse view of the DDFT (2) and the distended NB (1). B, The tip of the needle is visible as a hyperechoic structure within the boundaries of the NB (circle).

all but two cases this had no effect on correct injection of the bursa. In the remaining two cases, we used the technique described by Verschooten et al⁸ as this allowed us to restrain the foot in a Hickman block.

4. Discussion

Performing this procedure is facilitated when done in a dark room with a red light placed on the head of the operator. In doing so, the operator can maintain an overview on both the screen of the ultrasound machine, as well as the site of injection. Appropriate planning of needle placement is critical to have a successful procedure. If placed at the

level of or lateral to the unguis cartilage, needle insertion is very difficult. If placed too dorsal, needle penetration through the vascular bundle is possible. Detection of fluid in the NB and subsequent needle placement is facilitated in horses with “low heel” conformation and a wide space in between the bulbs. In horses with high and narrow heels obtaining good-quality images of the NB is challenging, which compromises accurate needle placement. Therefore, when first learning the technique, it is ideal to begin with horses with a foot conformation that promotes ultrasonographic visualization of the NB and eases needle placement.

Puncture of the DDFT is prevented with this method by using a lateral approach and ultrasound guidance. Recently, other ultrasound-guided DDFT-avoiding approaches were published. One approach used ultrasound guidance on the nonweight-bearing limb.⁵ The authors have used this technique and have found that it is more difficult to image small amounts of fluid and to work aseptically. Others describe an ultrasound-guided approach on the weight-bearing limb.⁴ However, this study describes the technique in cadaver limbs. To the knowledge of the authors, this is the first report of an ultrasound-guided tendon-sparing lateral approach of the NB in live horses.

5. Conclusions

Tendon-sparing NB injections can be performed with ultrasound guidance in standing horses. This is a safe procedure that avoids potential DDFT complications caused by needle penetration.

Acknowledgments

Declaration of Ethics

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



Fig. 4. Radiograph illustrating the presence of contrast agent within the NB after ultrasound guided injection.

Conflict of Interest

The Authors have no conflicts of interest.

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Retrospective Analysis of Lameness Localization in Western Performance Horses

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The distal forelimb and proximal metatarsus were the two most common anatomic regions of lameness based on response to diagnostic analgesia. Authors' addresses: Department of Clinical Sciences, College of Veterinary Medicine & Biomedical Sciences, Equine Orthopaedic Research Center, Colorado State University, Fort Collins, CO 80523 (Johnson, Frisbie); and La Mesa Equine Lameness Center, 8386 FM 455 E Pilot Point, TX 76258 (Donnell, J.; Donnell A.); e-mail: david.frisbie@colostate.edu. *Corresponding author; †presenting author. © 2017 AAEP.

1. Introduction

Similar to other high-level athletic disciplines, the Western performance horse experiences a variety of orthopedic conditions as a result of rigorous sport-specific physical demands. Although musculoskeletal injury rates have been quantified in other equine disciplines, this data are lacking for the Western performance athlete.

2. Materials and Methods

Records of diagnostic analgesia of Western performance horses competing at nationally sanctioned shows were retrospectively reviewed over a 1-year period to identify affected limb(s) and blocking patterns.

3. Results

A total of 216 lameness examinations on 212 horses were included. The average lameness grade was 2.25/5 with 120/216 (56%) cases being primarily forelimb in origin while 96/216 (44%) were hind-limb related. Forelimb lameness localized with a palmar digital, abaxial sesamoid nerve block or a combination in 37% of cases. The hind limb proximal metatarsal region was an identified source of lameness in 13% of

cases, which localized with a combination of a low plantar block or direct infiltration of the deep branch of the lateral plantar nerve (DBLPN). When categorized by specific block, a forelimb palmar digital localized 23% of cases, followed by a forelimb abaxial sesamoid (11%), a hind limb low plantar (10%), hind limb DBLPN (8%), and the stifle (7%).

4. Discussion

Determining the source of lameness through diagnostic analgesia remains challenging, but the continued assessment of response to diagnostic analgesia may help characterize discipline-specific injuries.

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Disclosures

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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.

How to Identify Proximal Palmar/Plantar Third Metacarpal/Metatarsal Bone Osseous Proliferation Using Ultrasound

Natasha M. Werpy, DVM, DACVR*†; and Caitlyn Redding, DVM†

Palmar/plantar osseous proliferation can be identified in horses with lameness localized to the proximal metacarpal and metatarsal regions and can be seen in conjunction with suspensory ligament abnormalities. Diagnosis of palmar osseous proliferation of the metacarpal/metatarsal bone allows the selection of proper management and aids in the determination of prognosis in these cases. This paper will describe how to identify palmar metacarpal/metatarsal bone osseous proliferation using ultrasound. Authors' addresses: Equine Diagnostic Imaging, 14313 SW 79th Street, Archer, FL 32618 (Werpy); and College of Veterinary Medicine, North Carolina State University, 1060 William Moore Drive, Raleigh, NC 27607 (Redding); e-mail: equinedxim@yahoo.com. *Corresponding author; †presenting authors. © 2017 AAEP.

1. Introduction

Suspensory ligament injury is an important injury in performance horses and based on the complexity of the injury can result in rest, rehabilitation, surgery, and/or retirement.¹ Suspensory ligament disease can vary from clinical signs of poor performance to marked lameness depending on the complexity of the injury. It is usually diagnosed using a combination of lameness examination, diagnostic nerve blocks, and ultrasound.^{2,3} The suspensory ligament itself is frequently not the only structure affected. The metacarpal/metatarsal bone can be affected as well, and therefore multiple imaging modalities, including radiographs, nuclear scintigraphy, and magnetic resonance imaging (MRI) are often needed to fully diagnose the extent of the injury.^{4,5} Injury to the suspensory ligament can be accompanied by enthesopathy characterized by bone loss and/or proliferation at the ligament attach-

ment as well as fluid accumulation affecting the palmar proximal metacarpal/metatarsal region. When lameness is localized to the proximal metacarpal/metatarsal region, there are additional abnormalities of note that can be identified with ultrasound as well as other methods of imaging. One of the abnormalities that can occur in the proximal metacarpal/metatarsal region with a similar clinical presentation as well as blocking pattern as a horse with primary suspensory ligament disease is palmar metacarpal osseous proliferation. In this case, there is osseous proliferation extending from the palmar medial or palmar lateral margin of the third metacarpal/metatarsal (mtc/mtt) bone between the axial surface of the second or fourth mtc/mtt bones and the adjacent suspensory ligament margin. Due to the location of this osseous proliferation, it can be extremely difficult to distinguish it from the axial surface of the second or fourth mtc/mtt bones without

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specific investigation of this region. The clinical relevance of the osseous proliferation can be variable depending on the size, shape, location, and any adjacent tissue abnormalities. These specific characteristics are evaluated, as is the relationship between the osseous proliferation and the suspensory ligament. This paper will review the anatomy of the proximal palmar/plantar mtc/mtt region and the relationship with the suspensory ligament, mtc/mtt bones, and the interosseous spaces in conjunction with the ultrasound techniques for identifying abnormal osseous proliferation in this region, which can then be incorporated in the standard ultrasound examination of the proximal metacarpal region.

Basic Anatomy

Forelimb Proximal Metacarpus and Suspensory Ligament

The suspensory ligament attaches at the proximal palmar aspect of the third metacarpal bone as well as the distal row of the carpal bones.³ The most proximal and palmar fibers are fused with the accessory ligament of the deep digital flexor tendon and attach at the palmar tubercles of the third and fourth carpal bones. These fibers cross the carpometacarpal joint space and join the main metacarpal aspect of the ligament. The main sagittal section of the ligament originates at the proximopalmar aspect of the third metacarpal bone with two lateral and medial attachments on the axial surfaces of the second and fourth metacarpal bones. At the level of the deep palmar metacarpal artery and vein anastomosis all of the attachments become two (medial and lateral) lobes that will fuse to become the body of the ligament.³ The body of the ligament continues distally until the suspensory ligament branches to then attach on the medial and lateral proximal sesamoid bones. One of the difficulties while ultrasounding can be attributed to the three tissue types that make up the ligament consisting of tendon fibers, striated muscle, and fat.³

The palmar margin of the third metacarpal bone is not necessarily flat at the attachment of the suspensory ligament. It has a sagittal crest on midline, which can vary in size and shape and is typically located at the division between the medial and the lateral suspensory ligament lobes. On either side of the sagittal crest the palmar surface of the third metacarpal bone can be flat to mildly concave. At the articulation of the second and fourth metacarpal bones with the third metacarpal bones the interosseous spaces become evident. The interosseous space (IOS) can be seen in the proximal one third of the mtc/mtt ending approximately at the level of the mid body of the suspensory ligament. The normal suspensory ligament has rounded medial and lateral margins immediately distal to the proximal extent of the attachment of the suspensory ligament on the third metacarpal bone.

Hind Limb Proximal Metatarsus and Suspensory Ligament

The suspensory ligament in the hind limb begins as a triangular shape at the proximal aspect of the third metatarsal bone, being thinner medially than laterally. The suspensory ligament in the hind is more lateral of midline with a close relationship to the axial aspect of the fourth metatarsal bone, more important proximally than as you move distally on the leg. There is a larger amount of connective tissue separating the second metatarsal bone from the suspensory ligament. The hind suspensory ligament is not bilobed and typically has a prominent area of central fibers as well as peripheral fibers, with the fat and muscle distribution being more symmetrical medially and laterally. As the ligament continues distally it becomes heart shaped to round and then oval, until it reaches the level of the bifurcation.⁴

2. Materials and Methods

Equipment

The ultrasound examinations were performed with a portable GE Logiq e Vet NextGen ultrasound machine with a 7-to-12-MHz linear probe. A standoff pad is not typically used.

Ultrasound Examination

Specific evaluation of the IOS should be incorporated into the standard ultrasound examination of the proximal mtc/mtt region as the clinical presentation can be similar to horses with desmopathy of the proximal suspensory ligament. The approach and techniques to identify palmar/plantar mtc/mtt osseous proliferation and injury to the suspensory ligament are the same. However, specific evaluation of the interosseous spaces and the palmar/plantar margin of the third mtc/mtt bone is necessary to make this diagnosis.

The evaluation of this region should be performed initially with the limb in the weight-bearing position using the palmar approach with assessment of the suspensory ligament and the mtc/mtt bone margins. During this examination, the probe angles should be varied to be perpendicular to the surfaces of interest. In addition, on and off angle imaging should be used to evaluate the soft tissues and bony surfaces. Following completion of the standard weight-bearing examination, the suspensory ligament and surrounding structures should be examined with the limb in the nonweight-bearing position. This technique uses the flexor tendon laxity to increase the contact surface of the ultrasound probe allowing complete visualization of the suspensory ligament as well as the axial surfaces of the second and fourth mtc/mtt bones and their relationship to the third mtc/mtt bone. In addition, this technique requires less depth allowing the use of higher frequency resulting in better detail and it makes manipulation of vessels possible, decreasing edge artifact.⁴ When beginning this

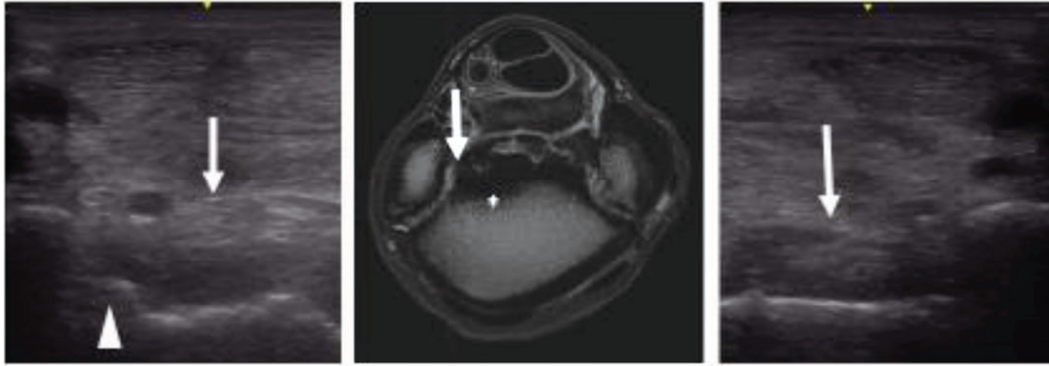


Fig. 1. MRI of the right fore with the corresponding ultrasound image (on the left) demonstrating a mild proximal palmar osseous proliferation on the third metacarpal bone (arrowhead) with mild to moderate enlargement of the medial lobe of the suspensory ligament (arrow) and mild bone resorption (asterisk) at the attachment of the medial lobe of the suspensory ligament. The left fore ultrasound image (on the right) shows a comparison of no osseous proliferation affecting IOS and a normal-sized medial lobe of the suspensory ligament (arrow).

exam, the ultrasound probe should be positioned parallel to the third mtc/mtt bone and the focal zones should be positioned within the area of interest. Following evaluation of the palmar margin of the third mtc/mtt bone, the relationship between the third mtc/mtt bone and the second and fourth mtc/mtt bones can be evaluated. The normal IOSs should be evident as focal linear echoluencies at the articulations of the third mtc/mtt bone with the second and the fourth metacarpal bones. The probe angle can be altered in order to identify the IOSs and in order to evaluate deeper into the IOS. The IOS will be identified by either sliding the probe medially and laterally or changing the probe angle and fanning. The appropriate choice is dependent on the shape and angle of the IOS, and will change with different horses and different limbs. Regardless of whether sliding or fanning the probe is most effective, an anechoic linear region

bordered by echogenic margins should be identified. In addition, there should be a thin layer of echogenic connective tissue between the axial margin of the second and fourth mtc/mtt bones and the adjacent margin of the suspensory ligament.

In contrast, when focal osseous proliferation is present extending from the palmar medial or lateral margins of the third mtc/mtt bone there is a step, seen as a hyperechoic horizontal line, between the palmar or plantar margin of the splint bone and the third mtc/mtt bone that is the result of bone extending from the third mtc/mtt bone across the IOS, which is obscured (Fig. 1). This finding can be quite subtle on the ultrasound images in comparison with the MRI and computed tomography (CT) images, given that the size of the step is determined by the distance between the palmar/plantar margin of the mtc/mtt bone and the palmar or plantar extent

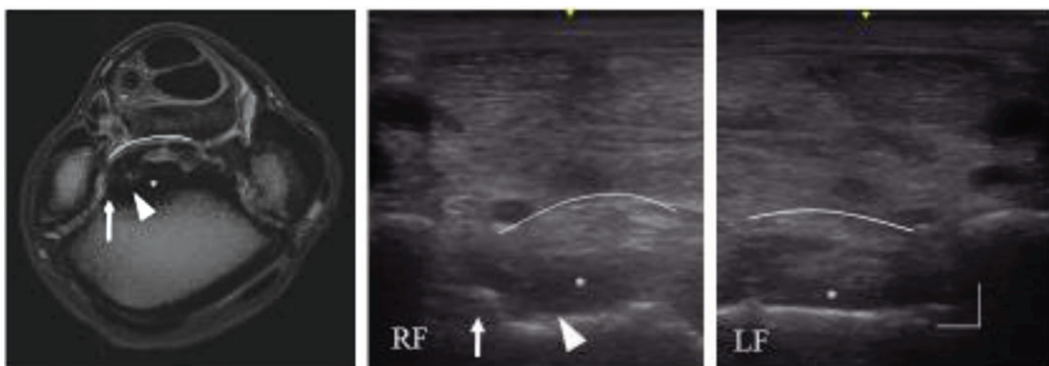


Fig. 2. MRI image of the right fore with the corresponding ultrasound images demonstrating a mild proximal palmar osseous proliferation on the third metacarpal bone (arrow) with mild to moderate enlargement of the medial lobe of the suspensory ligament (arrowhead) and mild bone resorption at the attachment of the medial lobe of the suspensory ligament. The left fore ultrasound image (on the right) shows a comparison of no osseous proliferation affecting the IOS. The right front vs left front ultrasound images show the increase in size in the size seen best by a rounded palmar margin of the medial lobe of the suspensory ligament (line) and abnormal suspensory ligament fibers (asterisk) of the right front suspensory ligament in comparison with the normal suspensory ligament of the left fore.

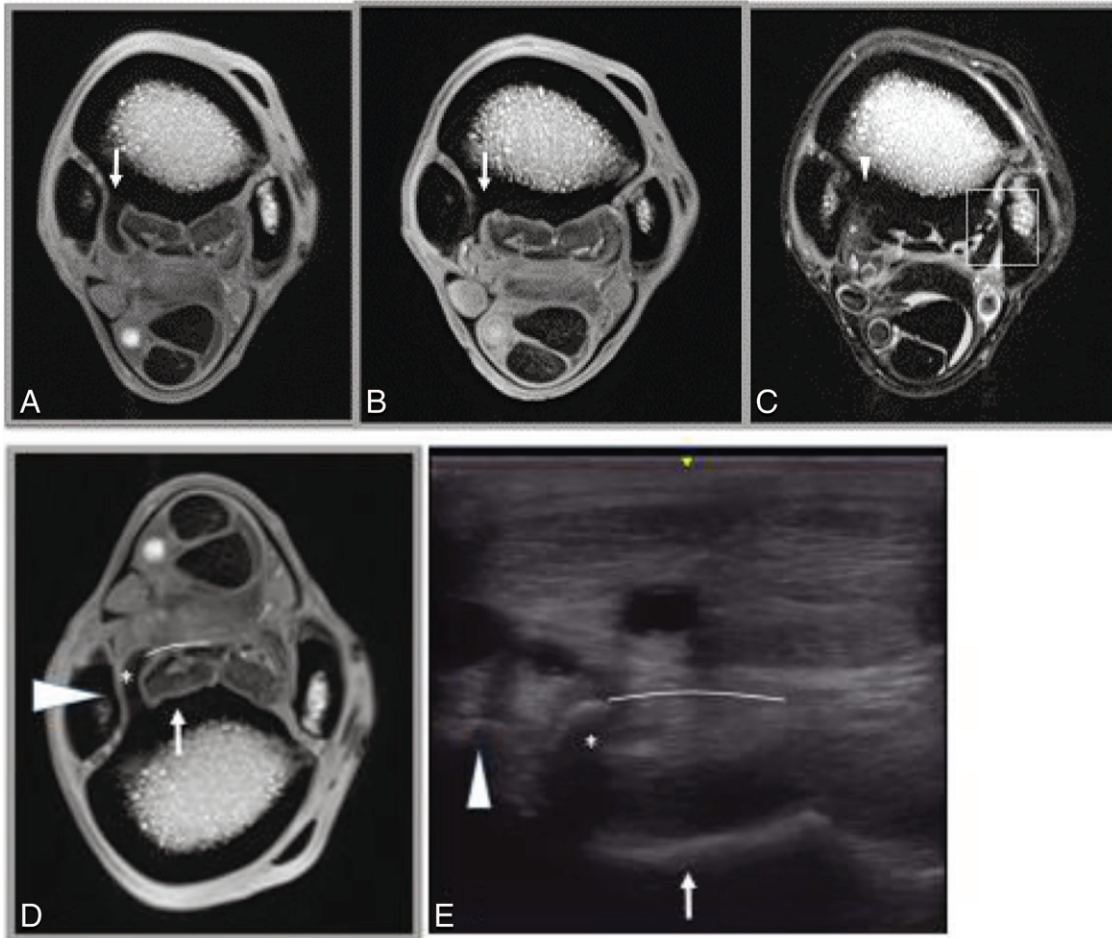


Fig. 3. The following magnetic resonance (MR) images show different sizes and shapes of the proximal palmar osseous proliferation of the third metacarpal bone. The images show contact of the osseous proliferation with the suspensory ligament with variable amounts of soft tissue abnormality could represent adhesions. A, This image shows a large smoothly margined thick osseous proliferation (arrow) with a shape change in the medial lobe of the suspensory ligament and associated mild fiber abnormalities. B, This image shows a large, sharply margined osseous proliferation with focal moderate fiber abnormalities at the dorsal aspect of the medial suspensory ligament lobe (arrow) adjacent to the osseous proliferation. C, This image shows a moderately sized, less well defined, irregular osseous proliferation (arrowhead) with extensive periligamentous tissue proliferation (asterisk) and possible adhesions to the medial margin of the suspensory ligament that is irregular with focal moderate fiber abnormalities, compared with the lateral side (outlined within the box). The MRI (D) corresponds to the ultrasound image (E) demonstrating a moderate proximal palmar osseous proliferation (asterisk) on the third metacarpal bone with mild to moderate enlargement of the medial lobe of the suspensory ligament (line). The osseous proliferation can be visualized on ultrasound as an additional linear osseous structure between the splint (arrowhead) and the palmar metacarpus (arrow).

of the osseous proliferation (Fig. 2). When osseous proliferation is identified, close evaluation of the suspensory ligament is necessary to determine whether this abnormality is affecting the suspensory ligament. Evaluation of the periligamentous space should be performed to determine the nature of the tissue between the suspensory ligament and the osseous proliferation (Figs. 3, and 4).

3. Results

Using this technique, the proximal mtc/mtt region can be evaluated to identify osseous and soft tissue abnormalities and specifically palmar or plantar osseous proliferation affecting the third mtc/mtt

bones. If the proximal mtc/mtt regions are not specifically evaluated for a “step” as previously described and the lack of a visible IOS, the osseous proliferation will appear as the normal axial surface of the splint. This technique is not difficult to perform as it is similar to the evaluation of the suspensory ligament region and only requires awareness of the shape changes in the bone surfaces.

This technique has been used to diagnose 13 horses. The information obtained from the ultrasound examination, as well as other modalities in certain cases, was used to determine appropriate case management, providing information to clinicians that could be used to determine whether the

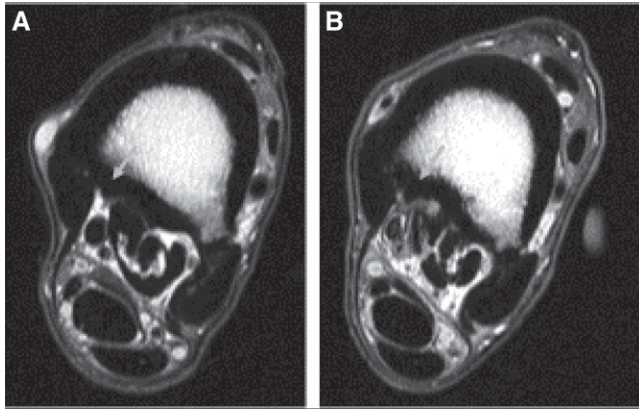


Fig. 4. MRI of a horse with bilateral proximal plantaromedial osseous proliferation (arrows) on the third metatarsal bones. A, There is moderate osseous proliferation with moderate fiber abnormalities affecting the dorsal suspensory ligament and moderate focal periligamentous tissue proliferation. B, There is mild to moderate osseous proliferation with moderate periligamentous tissue proliferation and focal moderate bone resorption at the attachment of the medial lobe of the suspensory ligament on the proximal third metatarsal bone.

case could be medically managed or if surgery was indicated (Fig. 5). In certain cases, following consultation with a board-certified surgeon, surgical removal of the osseous proliferation was elected (Fig. 6). Factors to consider with regard to this decision include size of the osseous proliferation, extent of suspensory ligament injury, amount of periligamentous tissue proliferation and possible adhesions, degree of lameness, and whether medical management had already been attempted. At this time long-term outcomes have not yet been established. Of the two horses that had surgery, one is retired due to the extent of the suspensory ligament injury and one remains in low level of work. The horses that have been medically managed, either still remain in rehabilitation or have not yet reached their previous level of activity. More time is needed to determine the outcomes of these cases.

4. Discussion

Suspensory ligament injury is complex and can be the result of soft tissue injury, osseous abnormalities, or a combination of the two. This technique will advance the diagnosis of abnormalities in the proximal mtc/mtt region. It should be incorporated

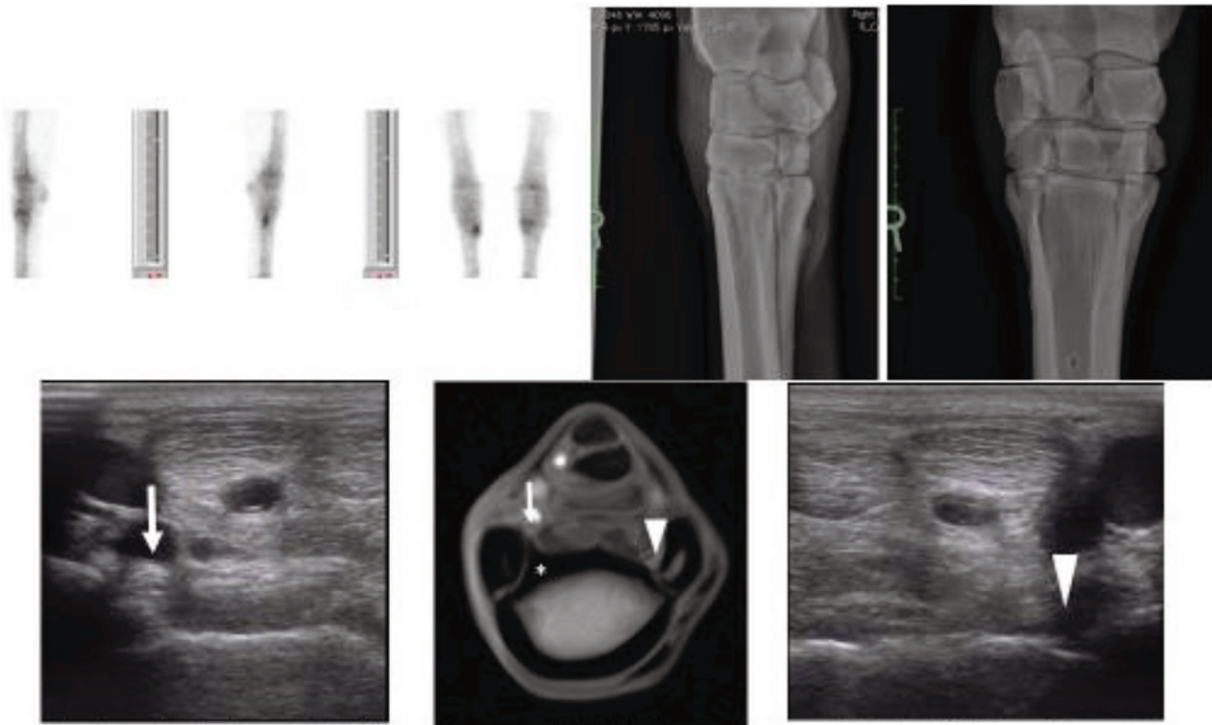


Fig. 5. Nuclear scintigraphy, radiographs, ultrasound, and MRI images from a case with Grade 2 lameness that improved 85% to local infiltration of the proximal suspensory ligament and was diagnosed with palmar metacarpal osseous proliferation that was surgically removed. MRI with corresponding ultrasound images demonstrate the “step” resulting from palmar osseous proliferation characterized by a horizontal hyperchoic line (arrow), that is seen overlying the interosseous space on the ultrasound image on the left vs the hyperechogenic visible proliferation. Nuclear scintigraphy images demonstrate increased radiopharmaceutical uptake in the region of the palmar osseous proliferation. The radiographs retrospectively have mild opacity superimposed over the medial IOS, although an obvious cause of lameness is not identified on the radiographs. The focal osseous proliferation on the palmar margin of the second metacarpal bone was not painful to palpitation and did not have increased radiopharmaceutical uptake.

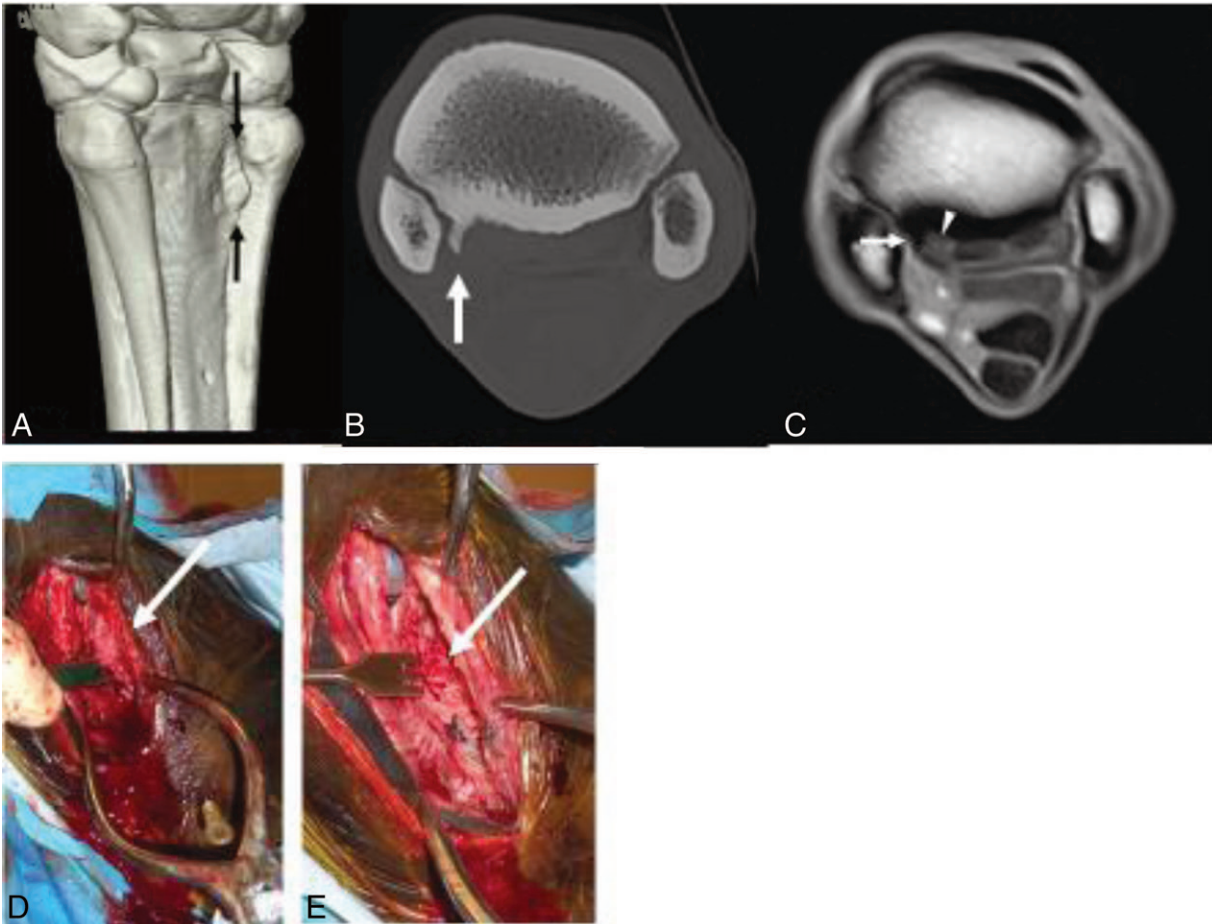


Fig. 6. A and B, CT and MRI (C) of proximal palmar osseous proliferation of the third metacarpal bone. Adjacent to the palmar osseous proliferation (arrow), there are focal moderate fiber abnormalities (arrowhead) in the dorsal aspect of the medial lobe of the suspensory ligament with mild to moderate resorption of the palmar third metacarpal bone at the medial lobe attachment. The osseous proliferation is more difficult to identify on the MRI when compared with the CT image given that it appears to be continuous with the medial suspensory ligament margin (arrow on C). D and E, Images of the osseous proliferation of the third metacarpal bone at surgery, from the previous CT images, to remove the region of bone. D, This is at the beginning of surgery and image (E) is after removal. Images courtesy of Dr. Alan Nixon.

into the standard examination of the proximal mtc/mtt regions as it utilizes a similar technique and then requires more specific evaluation of the interosseous spaces. Close scrutiny of this region will allow a diagnosis of the palmar/plantar osseous proliferation, which could otherwise easily be missed.

A linear probe is used by the authors to perform this examination. However, a microconvex probe could be used as angling the ultrasound beam parallel with the IOS will be more easily accomplished when compared with a linear probe. However, the authors find that the decreased detail of the microconvex probe to be prohibitive. This could vary among cases, operators, and machines.

Palmar or plantar osseous proliferation can be visualized on ultrasound examination when the IOS is obscured, typically seen as a step between the third mtc/mtt bone and either the second or fourth

mtc/mtt bones dependent on either medial or lateral location. It may not always be possible to distinguish whether the osseous proliferation is from the proximal palmar/plantar third mtc/mtt bone or from axial splint bone proliferation on ultrasound examination. However, advanced imaging can be used when needed, and will provide more detailed information about the suspensory ligament and surrounding soft tissue, which will be valuable information in determining appropriate case management. Management of these cases requires an accurate assessment of the amount and severity of the suspensory ligament injury, if any, and a similar assessment of the bone. This will directly affect management and prognosis. If this cannot be achieved, then advanced imaging should be used to determine the clinical relevance of the ultrasound findings. In horses with pronounced suspensory ligament injury, removal of the osseous proliferation

may prevent further ligamentous injury as a direct result of the proliferation. However, this does not remove the impact of the injury that has already been sustained.

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.

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Effect of Extracorporeal Shockwave Therapy on Growth Factor Expression from Equine Platelet-Rich Plasma

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1. Introduction

Platelet-rich plasma (PRP) and extracorporeal shockwave therapy (ESWT) are frequently used for treatment of musculoskeletal injuries in horses. The hypothesis of this study was that application of ESWT to PRP would increase the concentration of platelet-derived growth factor, isoform BB (PDGF-BB), and transforming growth factor β , isoform 1 (TGF β_1) released from the platelets.

2. Materials and Methods

PRP from six horses was subjected to four treatment conditions (positive control (single freeze/thaw cycle), negative control (resting), ESWT-S (standard probe), ESWT-P (power probe). Each PRP sample was contained within a silicon gel pad and treatments were administered. ESWT-S and ESWT-P samples received 300 pulses at 23 kV and 2 Hz. The standard and power probe delivered 8.5 and 4.4 mJ per pulse, respectively. The

samples were centrifuged and supernatant was collected. Growth factor concentrations were quantified by use of ELISAs.

3. Results

Growth factor concentrations of the positive controls were significantly higher than all other treatments for TGF- β_1 and PDGF-BB. Growth factor concentrations for both ESWT treatment groups were significantly higher than the negative controls for TGF- β_1 and PDGF-BB. There was no significant difference in TGF- β_1 and PDGF-BB concentrations between the two ESWT treatment groups.

4. Discussion/Conclusion

Release of growth factors from PRP was significantly increased *in vitro* following treatment with ESWT when compared with resting concentrations. The data supports the use of ESWT immediately following therapeutic injection of PRP into injured

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soft tissue structures in the horse to attempt to increase the concentrations of growth factors released from the platelets.

Acknowledgments

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Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.

Injuries of the Sagittal Groove of the Proximal Phalanx in Warmblood Horses Detected with Low-Field Magnetic Resonance Imaging: 19 Cases (2007–2016)

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Sagittal groove injuries of the proximal phalanx are an important cause of lameness in Warmblood horses and can require magnetic resonance imaging for diagnosis. Findings indicate that the prognosis for performance soundness in horses diagnosed with sagittal groove injury and concurrent osteoarthritis is poor. Authors' addresses: B.W. Furlong and Associates, 101 Homestead Road, PO Box 16, Oldwick, NJ 08858; and Advanced Equine Imaging of Wellington, 5320 S. Shore Blvd., Wellington, FL 33449 (Gold); Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois–Urbana, Urbana, IL 61802 (Gutierrez-Nibeyro); Equine Diagnostic Imaging, Inc., 14313 SW 79th Street, Archer, FL 32618 (Werpy); e-mail: sgold@bwfurlong.com *Corresponding author; †presenting author. © 2017 AAEP.

1. Introduction

This retrospective case series describes standing low-field magnetic resonance imaging (MRI) characteristics of sagittal groove injuries in Warmblood horses. This is the first report on the outcome of non-racing horses diagnosed with these injuries following conventional treatment.

2. Materials and Methods

Retrospective review of medical records identified 19 cases from January 2007 to 2016. Horses with an MRI diagnosis of sagittal groove injury, follow-up MRI, and clinical outcome information were included. Clinical examinations, diagnostic tests, and other imaging modalities were reviewed.

3. Results

All horses had MRI lesions consistent with sagittal groove injuries of the proximal phalanx and abnormalities of the sagittal ridge of the third metacarpal/metatarsal bone; 15 horses (79%) had concurrent osteoarthritis of the affected metacarpophalangeal/metatarsophalangeal (MCP/MTP) joint. Eighteen horses received conservative therapy and all horses had osseous abnormalities detected at the follow-up MRI. At follow up, 13 horses (68.5%) were lame and six horses (31.5%) were sound and performing at the previous level of exercise.

4. Discussion

Findings indicated for mature Warmblood horses, acute or chronic injuries of the sagittal groove of the

Research Abstract—for more information, contact the corresponding author

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proximal phalanx have variable MRI characteristics. Based on this sample, the prognosis for performance soundness in Warmblood horses diagnosed with sagittal groove injury and concurrent osteoarthritis is poor.

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.

Functional Electrical Stimulation (FES) and the Effect on Equine *Multifidi* Asymmetry

Diane Isbell, DVM; Sheila Schils, MS, PhD*; Suzan Oakley, DVM, DACVSMR; and Ugo Carraro, MD

Ultrasonographic evaluation of the cross sectional area (CSA) of the equine *multifidi* muscles pre- and post-functional electrical stimulation (FES) training for 8 weeks, compared with controls, was obtained on 12 horses. The overall CSA of right/left equine thoracolumbar *multifidi* showed significant ($P < .001$) improvement in symmetry of the *multifidi* after 8 weeks of FES training when compared with no significant change in controls. Authors' address: N8139 900th Street, River Falls, WI 54022; e-mail: sbschils@EquiNew.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

A clinical improvement in the right/left symmetry of the equine epaxial muscles has been an observed outcome of functional electrical stimulation (FES) training. Ultrasonographic measurements of the cross sectional area (CSA) of the right and left thoracolumbar equine *multifidi* muscles pre- and post-FES training, when compared with controls, was evaluated to determine objective changes in symmetry.

2. Materials and Methods

Twelve horses received FES treatments over the thoracolumbar epaxial muscles for 8 weeks. Twelve additional control horses received no FES treatments. Ultrasonographic measurements of the CSA of the *multifidi* muscles at 7 thoracolumbar levels were compared to determine right/left symmetry pre- and post-FES training. The same measurements during the same timeframe were also taken from the control group; *t*-tests were used to test for statistical significance.

3. Results and Discussion

The overall CSA of right/left equine thoracolumbar *multifidi* showed significant ($P < .001$) improvement in symmetry after 8 weeks of FES training. In addition, all individual levels were significantly improved in symmetry post-FES ($P < .05$). The control horse group was nonsignificant for symmetry for both overall and individual thoracolumbar *multifidi* CSA pre- and post-8 weeks.

Acknowledgments

Brian Kanable provided statistical analyses and the A&CM Carraro Foundation for Translational Myology provided technical support.

Declaration of Ethics

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

Conflict of Interest

Dr. Sheila Schils is a principle of the company EquiNew which provided the FES equipment and funded the statistical analyses. The remaining Authors have no conflicts of interest.

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How to Select and Manage Cases for Hindlimb Fasciotomy and Neurectomy

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1. Introduction

A horse owner recently said to me, "Gee it seems like hindlimb proximal suspensory desmitis is an epidemic among horses. I do not remember this problem from 20 or 30 years ago." It is true that since the mid 1990s, chronic hindlimb proximal suspensory desmitis has been diagnosed with increasing frequency^{1,2} and although it is possible that the disease process is occurring more frequently, it is just as likely that we are simply getting better at recognizing and diagnosing the problem. How to diagnose these injuries has been discussed previously and is beyond the scope of this paper. Although not discussed in this paper, localization and imaging remain important because still, even with advanced local anesthetic and imaging techniques, hind-limb proximal suspensory desmitis can be a hard diagnosis to make. This is due to the insidious onset of a commonly bilateral problem, which makes recognition of overt lameness difficult, the overlap of localizing blocks with other common diagnoses, the positive clinical response to treatments for other common

diagnoses, and the inherent difficulty of imaging the origin of the hindlimb suspensory.

Once diagnosed, the majority of horses with chronic hindlimb proximal suspensory desmitis treated with rest or medical therapy remain lame or have recurrent lameness after returning to work.^{1,3,4} The most often-cited theory for persistent lameness despite appropriate therapeutic programs is development of a compartment syndrome, in that the enlarged proximal suspensory ligament causes compression of and pain from the deep branch of the lateral plantar nerve (DBLPN),⁵ suspensory ligament, and underlying bone due to restriction from the deep plantar fascia. Since Andy Bathe performed his first hindlimb fasciotomy and neurectomy procedure in the late nineties and reported his findings at the annual meeting of the European College of Veterinary Surgeons (ACVS) in 2001 and later at the annual meeting of the American College of Veterinary Surgeons (ACVS),⁶ the procedure has become widespread in use. Several factors that should be considered prior to recommending surgery and will be outlined here.

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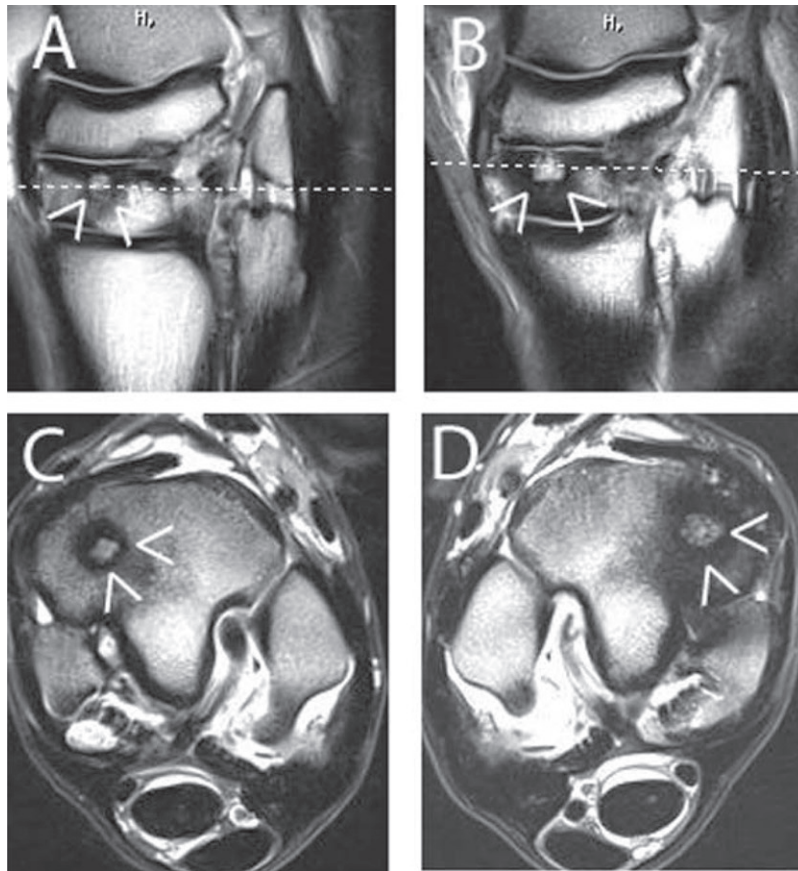


Fig. 1. PD-weighted MRI images from a horse that blocked to the suspensory region. (Left, A and C) left limb and (right, B and D) right limb. (Top, A and B) Dashed line on sagittal images represents the location of (bottom, C and D) transverse images. Carets highlight the cyst-like lesions.

2. Materials and Methods

How to Select Cases

Arguably the most important factor in selecting cases for fasciotomy and neurectomy is a correct diagnosis. In a nutshell, the lameness or performance problem must significantly improve after diagnostic anesthesia of the suspensory ligament region and the imaging of the suspensory ligament should match the clinical problem. In other words, if the lameness is severe and the imaging abnormalities of the suspensory ligament are mild or equivocal, other causes of lameness should be investigated. Some examples of other diagnoses we have made when the lameness blocked to a “suspensory block” have been third and central tarsal subchondral bone cysts (Fig. 1), bone edema in the fourth tarsal bone and proximal metatarsus, and severe osteoarthritis of the distal tarsal joints. Although horses with these pathologies can be blocked to “suspensory blocks” including DBLPN, direct suspensory ligament infusion and tibial nerve, it is unlikely that fasciotomy and neurectomy would improve the associated lameness.

Fig. 1 is an example of such a case: the horse was a 7-year-old Quarter Horse gelding used as a

Hunter, whose lameness resolved with a number of “suspensory blocks” but he did not have suspensory injury. The horse had a moderate-to-marked 3/5 right hindlimb lameness that switched to a mild 3/5 left hindlimb lameness after a direct infusion block of the suspensory ligament (6 mL). On the MRI, there are nearly matching subchondral bone cysts in the third tarsal bones with surrounding bone sclerosis (right worse than left). The suspensory ligaments were within normal limits. Diagnostic blocks were repeated after the MRI. Both a low-volume (3mL) DBLPN and a tibial nerve block (repeated on a different day) resolved the right hindlimb lameness and switched the horse to a mild left hindlimb lameness. Arthrodesis of the distal hock joints with articular drilling and application of bone plates was performed. The horse was sound and returned to full work including jumping 8 months later, and remained sound for available follow up of 18 months. This case is a good example of three different “suspensory blocks,” local infusion, DBLPN and tibial nerve, the resolved distal tarsal-associated lameness.

Not only should the horse’s lameness or performance problem significantly improve with diagnos-

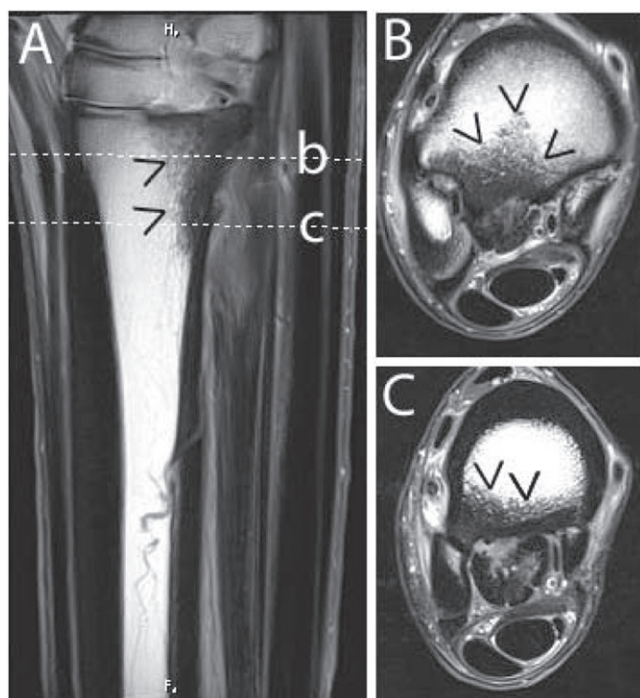


Fig. 2. PD-weighted MR images from a 16-year-old Thoroughbred used for upper level 3-day-eventing with suspensory ligament injury and concomitant bone lesion. A, Dotted lines at b) and c) on the sagittal image correspond respectively to transverse images (B and C). Carets correspond to bony sclerosis indicated by PD hypointensity.

tic anesthesia of the suspensory ligament region and the degree of injury during imaging of the suspensory ligament should match the clinical problem, but some have advocated that horses with concurrent bone lesions are not ideal candidates for fasciotomy and neurectomy. This is because of the concern that the lameness or performance problem will not respond as thoroughly or favorably to fasciotomy and neurectomy when there is concurrent bone pathology^{6,7} although this has not always been our experience (Fig. 2). The horse in Fig. 2 had a moderate-to-severe right hindlimb lameness (3/5) that improved significantly to a low-volume (2 mL) block of the DBLPN. On MR images, in addition to significant enlargement with abnormal signal intensity and pattern of the proximal suspensory ligament, there is marked proton density hypointensity (bone sclerosis; marked by carets) of the proximal metatarsus. Despite severity of suspensory ligament injury and severity of concomitant bone lesions, there was lameness resolution with return to upper level 3-day-eventing competition for the available follow up of 1.5 years following a fasciotomy and neurectomy. This horse is a good example of severe bony abnormalities on MRI that did not seem to negatively affect prognosis after a fasciotomy and neurectomy. Therefore, we do not think that concomitant bone lesions of the proximal plantar metatarsus are

a strict contraindication for fasciotomy and neurectomy; rather, we discussed with the owner that it may or may not negatively impact prognosis depending on the type and severity of the bone lesion.

Finally, lameness at secondary sites such as sacroiliac- or thoracolumbar-associated lameness are thought to be increased in horses with long-standing proximal hindlimb suspensory desmitis.⁸ Therefore, when the history and diagnostics indicate a very chronic injury, the clinician should examine the horse specifically for sacroiliac- or thoracolumbar-associated lameness. When it is present, it may limit the prognosis for resolution of the performance problem post fasciotomy and neurectomy. However, without surgery, it is unlikely that these horses will have any improvement in the performance problem or lameness. Additionally, it has been our experience and that of others (Andy Bathe, personal communication; March 12, 2017) that secondary sites of lameness in some horses can improve after the inciting problem is addressed with fasciotomy and neurectomy. Certainly, any other concurrent hindlimb lameness, whether secondary to the suspensory injury or not, should be kept in mind when recommending fasciotomy and neurectomy. Obviously fasciotomy and neurectomy will not address pre-existing secondary sites of lameness that are independent of suspensory injury and if the secondary lameness precludes athletic function, the fasciotomy and neurectomy should not be recommended.

How to Avoid Complications

There are a few contraindications to a fasciotomy and neurectomy procedure.

1. Hyperextended hindlimb conformation is a contraindication to fasciotomy and neurectomy. This conformation is known to significantly increase the risk of catastrophic failure of the suspensory apparatus following fasciotomy and neurectomy and thus the procedure should not be recommended in these cases⁸ (Fig. 3). If this complication were to occur, the horse may require fetlock arthrodesis of the affected limb(s) to survive long term.
2. Acute injury to the proximal suspensory ligament is a contraindication to fasciotomy and neurectomy. Although we find acute injury to the hindlimb proximal suspensory ligament to be rare in our practice of mainly sport horses, if the acute vs chronic nature is not obvious based upon clinical and ultrasonographic examination, we always recommend MRI to further delineate acute vs chronic injury. We think this is because denervation of the acutely injured suspensory ligament could lead to lesion expansion secondary to increased loading of the acutely injured suspensory ligament. An alternative approach would be to perform the fasciotomy and



Fig. 3. Photographs of horses with suspensory injury and (A) normal and (B–E) varying degrees of hyperextension of hock and fetlock. Hyperextension is a contraindication for fasciotomy and neurectomy because of increased risk of postoperative catastrophic suspensory ligament failure.

neurectomy, followed by a significantly longer rest and rehabilitation program. But we always choose to treat the acute suspensory ligament injury first, recommending the fasciotomy and neurectomy only after the acute suspensory ligament injury has healed and become chronic with continued lameness.

3. Other concurrent hindlimb lameness, when not secondary to the chronic suspensory associated lameness, should be kept in mind when recommending fasciotomy and neurectomy. If the second site of lameness precludes athletic function, the fasciotomy and neurectomy should not be recommended.

The Procedure

The fasciotomy portion of the procedure is aimed at sharp transection of the plantar fascia overlying the suspensory ligament. This results in immediate decompression of the suspensory ligament, DBLPN, and bone due to the presumed compartment syndrome. The neurectomy portion of the procedure is aimed at removal of an approximately 2- to 3-cm section of the DBLPN from its origin off the lateral plantar nerve to just proximal to the proximal border of the plantar fascia where the DBLPN dives under the fascia. Removal of the nerve results in immediate desensitization of the origin of the suspensory ligament and denervation atrophy of the muscle fibers⁹ within the suspensory ligament. In our practice of mostly sport horses, bilateral fasciotomy and neurectomy is by far more common

than unilateral surgery due to the preponderance of bilateral injury. Whether an apparently normal contralateral limb should also receive fasciotomy and neurectomy during the same surgical episode when the diagnosis has been made unilaterally is currently unknown.⁸

How to Manage in Postoperative Period

The postoperative care of fasciotomy and neurectomy is somewhat variable among surgeons, but generally consists of 2 to 3 weeks of bandaging followed by 2 to 6 weeks of walking and/or walking and trotting exercise.^{7,8} When the suspensory lameness is mild, bilateral, and/or very chronic, there is often secondary atrophy of the gluteal musculature that should be addressed with a longer period of walking under saddle and other conditioning exercises prior to resumption of full work.

We advocate a recheck ultrasound examination prior to resumption of canter work under saddle. In our practice, this is 2 months from surgery. This exam is to check for iatrogenic lesions on the plantar surface of the suspensory ligament that can occur but do not appear to affect prognosis⁸ as well as new injury to the suspensory ligament. We have begun recommending this recheck ultrasound exam because of rare anecdotal reports of catastrophic suspensory ligament injury in the first 4 months after fasciotomy and neurectomy, even when the hindlimb conformation was considered normal preoperatively.^{7,8} At the recheck ultrasound, if the preoperative ultrasound was abnormal, the suspen-

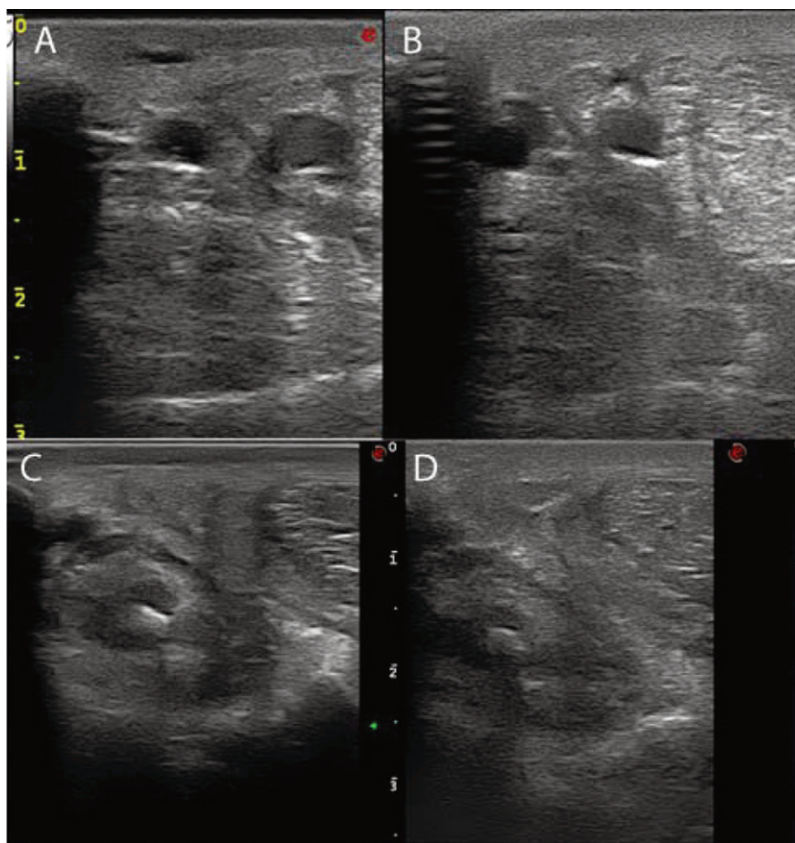


Fig. 4. Standard transverse sonogram (top, A, B) and angle contrast ultrasonography, (bottom, C and D) of a horse before (left, A and C) and 3 months after (right, B and D) fasciotomy and neurectomy. Notice the more triangular shape and less rounding of the lateral border postoperatively.

sory ligament typically has unchanged or improved fiber pattern, smaller size, and more normal (triangular) shape⁸ (Fig. 4). Additionally, it is our impression that the area of the deep plantar fascia may seem hypoechoic and slightly thickened when compared with preoperative sonograms at early rechecks. It is possible that both decompression by the fasciotomy⁸ and denervation atrophy of suspensory ligament muscle fibers^{8,9} contribute to the smaller and more normal appearance of the suspensory ligament after surgery.

It has also been noted that some horses will need intra-articular injection of corticosteroid to the tarsometatarsal joint as they return to full work after a fasciotomy and neurectomy.⁸ This may be because of biomechanical changes to the suspensory apparatus secondary to muscle fiber atrophy⁸ or it could be due to other factors.

3. Results

When cases are selected appropriately for fasciotomy and neurectomy, the complication rate is very low and the prognosis for full return to work is very good with approximately 80% of horses returning to the previous level of work for at least 1 year.^{6,8} It has been our experience and that of others (Sue

Dyson, personal communication; Focus of Soft Tissue Lameness, New Orleans, LA, 2016) that when the horse responds favorably to fasciotomy and neurectomy, the long-term outcome beyond 1 year is excellent. This is in contrast with neurectomy of the palmar digital nerves for foot lameness, where recurrent lameness is an expected long-term result secondary to re-innervation. We think the improved ultrasonographic appearance postoperatively of the suspensory ligament in size, shape, and pattern, or the possible permanence of the fasciotomy, or both, explains why the long-term prognosis is so good. If the ligament permanently changes following fasciotomy and neurectomy with resultant reduced injury risk, there may not be recurrent lameness even with complete re-innervation of the proximal suspensory ligament which is possible and even likely post-neurectomy.

Owners should be warned of the likelihood of a curb-like swelling at the surgery site and the possibility of white hairs (Fig. 5).

4. Discussion

Unlike nearly 20 years ago, there is hope for the majority of horses to have a continued athletic career when the diagnosis of chronic hindlimb proximal sus-

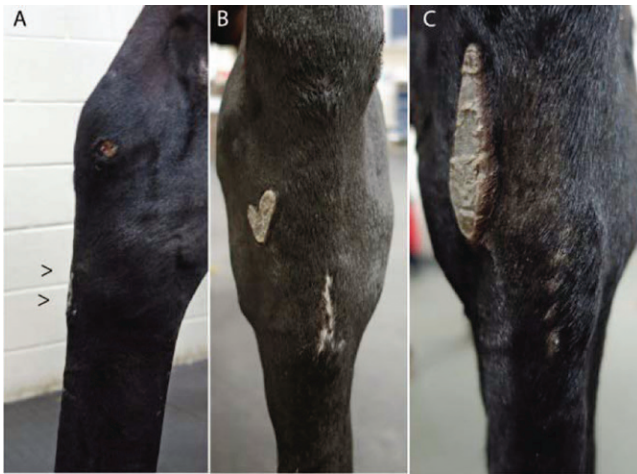


Fig. 5. Photographs post fasciotomy and neurectomy. There is a (A) curb-like swelling (marked by carets) and (B and C) white hairs at the surgical site. When present, the amount of white hair is typically more similar to that seen in (C).

pensory desmitis has been made. Fasciotomy and neurectomy has become a widely accepted treatment and results in approximately 80% of horses returning to their previous level of work.^{6,8} To achieve this success rate, it is critical that the preoperative diagnosis is correct and other lesions that can also improve with “suspensory blocks” are ruled out. The value of MRI to fully rule out other or additional lesions that improve with “suspensory blocks” cannot be understated. Despite a very low complication rate, when complications occur, they can be devastating.^{7,8} Thus it is important for clinicians to recognize the appropriate indications and clearly defined contraindications prior to recommending fasciotomy and neurectomy.

Clinical Checklist Prior to Recommending Fasciotomy and Neurectomy

- The lameness or performance problem must improve with diagnostic anesthesia to the suspensory ligament region and the imaging of the suspensory ligament should match the clinical problem (in severity, for example).
- There should be absence of significant injury to other structures that could improve to a suspensory ligament block (bone pain from MT3, distal tarsal pain, fetlock joint pain, etc.).
- Contraindications are not present.
 - Normal (not hyperextended) hock and fetlock joint angle.
 - Chronic (not acute) desmitis i.e., no core lesion on ultrasound, increased echogenicity of the tendinous portion in angle con-

trast ultrasonography (ACUS), or T2 hyperintensity on MRI.

Owner Communication Checklist Prior to Recommending Fasciotomy and Neurectomy

- Owner warned of curblike swelling and possibly development of white hairs at surgical site.
- Owner warned of very rare occurrence of horses experiencing catastrophic breakdown of the suspensory ligament after fasciotomy and neurectomy, even when pre-operative hock and fetlock conformation is considered normal.^{7,8} To our knowledge, these extremely rare, anecdotal occurrences have all been within the first 4 months postoperatively.
- Owner instructed to seek recheck ultrasound exam prior to resumption of full work, or 6 to 8 weeks from surgery, to check for development of hypoechoic suspensory ligament lesions.

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.

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Determination of the Time Required to Achieve Maximum Synovial Fluid Concentration of Amikacin in the Distal Interphalangeal Joint Following Intravenous Regional Limb Perfusion

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The peak synovial concentration (C_{\max}) using 2 g amikacin sulfate occurred at 15 minutes and did not increase despite maintenance of the tourniquet. Tourniquet application of 15 minutes is sufficient for completion of intravenous regional limb perfusion (IVRLP). Authors' addresses: Department of Surgical and Radiological Sciences (Kilcoyne, Nieto, Dechant) and the K. L. Maddy Equine Analytical Chemistry Laboratory (Knych), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; e-mail: isabellekilcoyne@hotmail.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

When performing regional limb perfusions tourniquet application of up to 25 to 30 minutes have been reported in previous studies. No study to date has determined the actual synovial C_{\max} and time to C_{\max} following instillation of the perfusate to identify the ideal time to maintain the tourniquet.

2. Materials and Methods

Horses underwent intravenous regional limb perfusion (IVRLP) using standing sedation with 2 g amikacin sulfate diluted to 60 mL using 0.9% saline in the cephalic vein of a front limb using a pneumatic tourniquet. Synovial fluid was collected from the

distal interphalangeal (DIP) joint at 5, 10, 15, 20, and 30 minutes after complete instillation of the perfusate. The tourniquet was removed after the 20-minute sample was collected. Blood samples from the jugular vein were also collected at 5, 10, 15, 19, 21, 25, and 30 minutes after IVRLP. Amikacin was quantified by a fluorescence polarization immunoassay. The median peak concentration (C_{\max}) of amikacin and the time to median peak concentration (T_{\max}) within the DIP joint was determined.

3. Results

The median C_{\max} for the DIP joint was 550 (range, 36.7 to 2167) $\mu\text{g/mL}$. The median T_{\max} for the DIP joint was 15 minutes.

Research Abstract—for more information, contact the corresponding author

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4. Discussion

Application of the tourniquet for 15 minutes is sufficient to achieve peak synovial concentrations of amikacin within the DIP joint. Use of a shorter tourniquet time could reduce discomfort experienced by the horse and the level of sedation required.

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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.

Impact of Pulmonary Disease on Performance: A Review

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1. Introduction

Horses are exceptional athletes because of a range of anatomic, functional, and genetic attributes that, coupled with the appropriate training, may result in the desired level of performance. Poor performance refers to horses that may train properly but are experiencing a decrease in performance level or horses unable to exercise at an expected level based on their physical characteristics, genetic potential, and training status. The term exercise intolerance is usually reserved for horses that are more severely affected and not capable of training properly, let alone performing at the expected level. A variety of conditions are associated with poor performance in the athletic horse. The majority of problems associated with poor performance involve musculoskeletal, respiratory, and cardiovascular diseases. A significant proportion of poorly performing horses are affected by a combination of problems often involving different body systems. This finding underscores the value of a systematic diagnostic approach to cases of poor performance.

In order to understand what factors might negatively impact performance, it is important to first recognize the physiologic responses to exercise and adaptations occurring with training. The next step is to appreciate the contribution of the various body

systems to exercise and how they might impose limits on performance based on the type of exercise, fitness level, as well as work intensity. In addition, critical assessment of performance using objective or subjective criteria is an essential aspect of the workup of poorly performing horses. The discussion that follows will be focused on the effect of pulmonary diseases on the horse's performance. Knowledge of how respiratory diseases cause poor performance in horses and the value of various diagnostic tests at detecting these diseases will allow practitioners to implement targeted therapy and management strategies.

2. Assessment of Performance

Physiology of Performance in the Horse

Athletic performance is dependent on intrinsic factors including physical aptitude, adequate energy production, maximal aerobic capacity, stores of energy substrates, intramuscular mitochondrial volume, splenic contraction, gait efficiency, thermoregulation efficiency, and well-trained musculoskeletal and cardiovascular systems. An additional factor, all too familiar to horsemen and difficult to assess, is the mental factor or the will to win.¹ Energy required for muscle contraction is produced in two major ways: anaerobic metabolism, which requires

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glycogen or glucose; and aerobic metabolism, which requires oxygen as well as a combustible such as glucose, glycogen, or fatty acids. The source of energy used depends on the intensity of exercise as well as on its duration. Anaerobic energy production is very rapid but does not last very long. Aerobic energy is produced at a slower pace, but yields 13 times more adequate energy production and lasts as long as there is a combustible (oxygen, glycogen, fat). It is estimated that Quarter Horses running quarter-mile races generate about 60% of their energy needs via anaerobic metabolism and the remainder via aerobic metabolism.¹ In racehorses running a mile, 80% of energy needs are derived from aerobic metabolism. Fat becomes the main source of energy during low-intensity exercise such as endurance racing. Aerobic energy delivery depends on pulmonary diffusion of oxygen, hemoglobin concentration, heart rate, stroke volume, and oxygen extraction by muscles. The oxygen transport chain includes oxygen concentration in air (affected by altitude), oxygen transport via the respiratory tract, oxygen diffusion across alveolar capillary barrier, oxygen binding to hemoglobin and distribution to muscle via circulation, and finally, oxygen diffusion from capillary to myocyte and mitochondria.

There is an integrated adjustment of the various body systems in response to exercise. First of all, a horse's athleticism is in part due to its large lung and cardiovascular capacity (the lung volume and heart weight of a 1000-lb horse are twice as large as that of a 1000-lb steer). As the horse starts to exercise, there is a rapid increase in ventilation and cardiac output to match the increased oxygen demand from exercising muscles.² At peak exercise, the volume of air inhaled per minute increases 30-fold while the heart rate increases approximately 8-fold in combination with an increase in stroke volume that result in cardiac output 10-fold higher than resting values.² Greater than 80% of cardiac output flows toward exercising muscles during strenuous exercise. As a result, peak oxygen consumption (VO_2max) is 40-fold higher during strenuous exercise than resting level. As exercise intensity increases, blood lactate concentration rises exponentially.

Training results in physiological adaptations by a variety of body systems. Bone remodeling in response to the additional mechanical stresses imposed by repeated bouts of exercise results in strengthening of bone regions subjected to highest loads. A more readily visible adaptation is the increase in muscle mass due to fiber hypertrophy accompanied by increased capillary and mitochondrial density. Similarly, cardiovascular remodeling occurs with training, causing a rise in heart mass and stroke volume as well as an increase in red-blood-cell mass associated with up to a 15% elevation in hemoglobin concentration. Those adaptations result in a relatively slower heart rate for a given speed and up to a 25% increase in VO_2max ; however, maximum heart rate during strenuous exercise does

not change with training.³ Unlike other organs, the respiratory tract function does not improve with training and vital capacity or maximum minute ventilation remain the same in response to exercise.

How Do We Define and Evaluate Performance?

In order to determine the cause(s) of poor performance, it is essential to be in agreement with the horse's owner or trainer concerning the complaint (e.g., fading in the last quarter mile, abnormal respiratory noise, coughing, etc.). This step is essential to selecting appropriate diagnostic tests and assessing therapeutic efficacy. Assessment of performance in horses is highly dependent on the type of athletic activity. In racehorses, performance on the track may be measured objectively by speed, running time, finishing position, distance behind winner, and earnings. However, standardization of measurements is difficult because a large number of horse-related factors (sex, age, horse quality, fitness level, etc.) and other factors unrelated to horses (trainer, jockey, distance, purse, weight carried, track conditions, environmental conditions, etc.) may vary between races and confound results. Sophisticated statistical analyses are required to control for the effects of confounders on performance outcomes.⁴ Control of confounding factors are more feasible when horses are running on a high-speed treadmill; however, most studies suffer from low sample size and statistical power. Also, the relevance of performance data obtained during treadmill studies to track performance during racing has not been established for all disciplines.^{5,6} In competitive sports other than racing and in pleasure horses, measurement of performance is more subjective and difficult to assess. An owner or trainer's complaint of poor performance may be due to the horse coughing while being ridden, to a perceived decrease in willingness to perform, because of increased respiratory efforts during exercise, or prolonged recovery period following exercise. In such cases, assessment of performance has been conducted by asking owners or trainers to rate performance using semiquantitative systems such as visual analog scales or performance scores.⁷⁻⁹

Alternatively, performance may be evaluated by measuring physiological parameters collected during field or treadmill testing with portable equipment that now allows simultaneous recording of heart rate and velocity data, measurement of lactate concentration using point-of-care units, and overground endoscopy and measurement of respiratory gases using portable systems.¹⁰⁻¹² Evaluation of physiologic parameters may be conducted in two ways: 1) by evaluating data from a poorly performing horse against those from a database generated from comparable horses using a predetermined protocol; 2) by comparing parameters collected longitudinally on the same horse. The most challenging cases are horses that have not competed yet ("unproven") and that are not performing up to the ex-

pectation of the owner or trainer. In such cases, it is important to follow a protocol that allows systematic evaluation of all relevant body systems in order to rule out known causes of poor performance. In the end, the absence of evidence explaining why a horse is not performing will suggest one of three possibilities: 1) a behavior/psychological problem, 2) limited ability, or 3) undiagnosed pathology.

Poor performance can result from a variety of causes besides respiratory diseases. More importantly, it is common to diagnose several problems in the same horse.^{5,6} This is why it is important to perform a comprehensive evaluation of poorly performing horses.

3. Pathophysiology of Poor Performance

Healthy and fit racehorses experience marked exercise-induced arterial hypoxemia and hypercapnia during exercise at intensities above 80% of VO_2max .¹³ It is estimated that 75% of exercise-induced hypoxemia is due to diffusion limitation and 25% secondary to insufficient ventilation relative to metabolic needs. Therefore, respiratory function is the main constraining factor to performance in fit and sound horses competing in short-duration, high-intensity exercise (Quarter Horse, Thoroughbred, Standardbred racehorses). In this context, even a mild degree of airway obstruction or pulmonary disease may further compromise oxygen delivery to tissues and potentially lead to decreased performance.^{14–16} For horses exercising from moderate (50–80% VO_2max , e.g., jumping, dressage, endurance) to low intensity (<50% VO_2max , e.g., Western pleasure, trail riding), the effect of respiratory disease on oxygen delivery and performance is dependent on the severity of the condition in relation to oxygen demand. Fatigue results from insufficient oxygen delivery and failure to produce sufficient energy for exercising muscles.

Blood lactate concentration rises exponentially with running speed and this relationship is affected by training. Velocity corresponding to a blood lactate of 4 mmol/l (VLa4) is the most repeatable and reliable indicator of fitness level (“anaerobic threshold”) and performance ability in race and sports horses.^{17,18} Lactate is a by-product of anaerobic metabolism that rises in blood as energy demand increases with exercise intensity while oxygen delivery plateaus. When oxygen delivery is further compromised by respiratory disease, blood lactate levels increase faster resulting in a lower VLa4; however, other causes of decreased performance such as lameness or cardiac diseases may also be associated with lower VLa4 values.¹²

4. Effect of Pulmonary Disease on Athletic Performance

Inflammatory Airway Disease (Mild-Moderate Equine Asthma)

Horses with inflammatory airway disease (IAD) usually have a history of cough, increased airway

mucus, and decreased performance or delayed recovery after exercise. Scoring of tracheal mucus in horses with chronic airway inflammation has been validated.¹⁹ There is a strong association between poor performance and mucus accumulation in the trachea, both in racehorses and sports horses.^{8,20,21} Detection of more than a few blobs of mucus (i.e., score >1) in the trachea after a race is associated with higher race placing in both Standardbreds and Thoroughbreds.^{20,21} More pronounced accumulation of mucus that forms a continuous stream in the trachea (score >2) has been associated with poor willingness to perform as assessed by riders of horses competing in dressage and show-jumping.⁸

Bronchoalveolar lavage fluid (BALF) cytology allows recognition of different phenotypes in horses with IAD including neutrophilia, eosinophilia, and mastocytosis.²² Neutrophilic airway inflammation (>5%) has been associated with poor performance in Thoroughbred and Standardbred racehorses as well as endurance horses.^{5,12,23–25} Similarly, BALF eosinophilia (>1%) and hyperresponsiveness has been reported in some poorly performing racehorses.²⁶ In a recent prospective study in Thoroughbred racehorses, we found a significant negative correlation between performance and BALF neutrophils and mast cells (unpublished data).

In racehorses, tracheal wash fluid neutrophilia has been associated with coughing;²⁷ however, there is no association with performance.^{28,29} Similarly, there is no correlation between tracheal wash and BALF cytology.

Recurrent Airway Obstruction (Severe Equine Asthma)

Recurrent airway obstruction (RAO) or heaves is an allergic disease characterized by frequent cough, excess mucopurulent secretions in the tracheobronchial tree, abnormal respiratory sounds, and increased respiratory efforts. Exercise intolerance is usually marked but highly dependent on the level of exertion required of the horse as well as severity of airway obstruction. Horses with mild respiratory signs at rest may show abnormally increased respiratory efforts for a given level of exercise or exhibit prolonged recovery post-exercise. Because of a lack of “normal” cardiopulmonary variables during exercise and recovery period in healthy sports/pleasure horses, most of the assessment concerning exercise intolerance is based on owner or trainer’s perception.

Cytologic evaluation of BALF from RAO-affected horse reveal marked neutrophilia (>20%) with normal total nucleated cell count (<400 cells/ μL). Similarly, tracheal wash fluid analysis usually demonstrates an increased neutrophil percentage (>50%).

Horses during an acute exacerbation of the disease exhibit abnormal gas exchanges at rest leading to hypoxemia and sometimes hypercapnia.^{30,31} These blood gas abnormalities are mainly the result of ventilation-perfusion mismatch and increased dead-space ventilation. Horses with mild clinical signs usually have normal blood gases. During ex-

ercise, the degree of exercise-induced hypoxemia and hypercapnia is markedly worse in RAO horses in crisis compared with when they are in remission.³² Deterioration in gas exchanges appears to be mainly due to further deterioration in ventilation-perfusion relationship and is associated with exercise intolerance.

Exercise-Induced Pulmonary Hemorrhage

The blood may be either seen directly at the nose (epistaxis) or within the tracheobronchial airways by endoscopy. Alternatively, pulmonary hemorrhage may be inferred from the presence of hemosiderophages or excess red blood cells in tracheal wash or bronchoalveolar lavage fluid. The most accepted pathogenesis of exercise-induced pulmonary hemorrhage (EIPH) is pulmonary capillary rupture secondary to excessive transmural pressure in the pulmonary capillary circulation during strenuous exercise resulting in extravasation of red blood cells into the alveoli.³³ Strenuous exercise is also associated with large swings in alveolar pressure. Subatmospheric pressure in alveoli during each inspiration adds to capillary blood pressure to generate high transmural pressures. In chronic bleeders, pulmonary vein remodeling and wall thickening in combination with high pulmonary artery pressure likely contribute to more extensive pulmonary capillary ruptures.³⁴

Based on results from a recent systematic review, high-quality studies conducted during regular racing meets have shown that EIPH is associated with worse finishing (inferior position and farther behind winner) and lower race earnings (moderate-quality evidence).³⁵ Lower-quality studies failed to demonstrate an effect of EIPH on performance. There is some evidence of a dose-response relationship between EIPH and performance; that is to say, more severe EIPH is associated with worse performance. There is no doubt that severe (Grade 4) EIPH negatively affects performance in racehorses. However, the effect of the more common mild or moderate EIPH (Grade 1–3) on performance has been more variable. Depending on the study, EIPH of at least Grade 1 or at least Grade 2 severity is associated with decreased performance in Thoroughbred racehorses.^{36,37} However, EIPH severity is not associated with decreased performance in barrel racers; in fact, horses with Grade 4 bleeding were significantly faster than horses with lower grades in one study.³⁸ While the prevalence of EIPH is high based on cross-sectional studies in racehorses, the number of bleeding episodes visible by endoscopy in a given horse is relatively small compared to number of starts (~3 of 15 endoscopies).³⁹ Racing career duration is similar among horses with no EIPH detected by endoscopy or horses with Grades 1–3; however, horses with Grade 4 are more likely to have shorter careers.⁴⁰ Some studies have shown that horses exhibiting EIPH experience a more severe exercise-induced arterial hypoxemia than horses without

EIPH.^{14–15} This mechanism may explain the negative impact of EIPH on performance.

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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.

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Diagnosis of Pulmonary Disease in Athletic Horses

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Pulmonary diseases affecting athletic horses are often a challenge to diagnose because a mild decrease in lung function can have a dramatic effect on performance of these horses. This section describes the clinical signs and ancillary tests performed to diagnose noninfectious lung pathologies affecting athletic horses. Standardized techniques currently or under development to diagnose inflammatory airway disease (IAD) and exercise-induced pulmonary hemorrhage (EIPH) are described. Author's address: University of Calgary, HRIC-GAA10, 3330 Hospital Drive, NW, Calgary, AB T2N 4N1, Canada; e-mail: rleguill@ucalgary.ca. © 2017 AAEP.

1. Introduction

Infectious pathologies affecting horses' lower airways have a dramatic effect on their athletic capacity and usually present with obvious clinical signs that are not often representing a diagnostic challenge. To the contrary, noninfectious lower airway pathologies can induce subtle clinical signs and are more challenging to diagnose by practitioners. This section will therefore not describe diagnostic techniques used for infectious lung diseases but will rather focus on noninfectious lower airway pathologies of the performance horses.

Pathologies that impede airflow along the airway tract (from the nostrils down to the alveoli) will affect the horses' athletic capacity. Horses have a large lung capacity, with minute ventilation greater than 1850 L/min¹ described in trained Thoroughbreds during maximum exercise. Therefore, they can easily compensate for mild-to-moderate impairment of their lung function when not exercised at maximal capacity. This explains why clinical signs can be subtle and pathologies can be unnoticed if the

horses are trained in a submaximal or limited aerobic type of exercise. This was also reflected in a study by a very high owner satisfaction with the clinical status of their horses although they were affected by recurrent airway obstruction (RAO).²

The objectives of this article are 1) to describe clinical signs that can be associated with pulmonary disease in athletic horses and warrant further ancillary testing, 2) describe the endoscopic and imaging techniques used in these horses, 3) describe airways sampling technique and interpretation of the results, and 4) describe the lung function tests available for diagnosing pulmonary diseases in the athletic horse.

Clinical Signs Warranting Diagnostic Testing for Respiratory Diseases

It is important for the clinicians to know the information on the clinical signs associated with lung pathologies of the athletic horse because they allow gathering the most relevant information from the owners to increase the accuracy of a diagnostic plan. Clinical signs can be subtle but they usually have a

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good sensitivity to detect respiratory problems in athletic horses.

Cough

Cough has been strongly associated with pulmonary inflammation.^{3,4} It is a sensitive, but not specific, indicator of lower airways inflammation when sufficient observation time is allowed to monitor for coughing; because of the intermittent nature of the coughing, an observation time of at least 1 hour is recommended to increase the sensitivity of cough detection.⁴ This long observation time also explains why coughing is detected more reliably by horse owners than by the treating veterinarians. Coughing can be reported as a number of coughs per hour or more generally as a categorical scale like no cough/occasional cough/frequent cough,^{2,4} or by asking the owner to quantify it using a “visual analog scale.”^{5,6} Coughing has been shown to be associated with the presence of mucus in the trachea, as well as with pulmonary neutrophilic inflammation.^{3,4,7} Severe coughing has been shown to be associated with abnormal lung auscultation, labored breathing at rest, and decreased blood oxygenation in a controlled study on RAO horses.²

Nasal Discharge/Mucus

Mucus can be seen at the nostrils at rest, after exercise, or within the upper and lower airways during an endoscopic examination. Tracheal mucus scoring and association with lung inflammation is described below. Nasal discharge has been reported by owners with a high prevalence in horses with lung inflammation⁷ and with RAO.² Nasal discharge is often described as present/absent, but quantifying nasal discharge objectively is challenging. To our knowledge, only one study described a clinical nostril mucus score but it needs further validation before it can be used in an objective manner reliably.⁸ Horses with RAO that are reported by owners to have nasal discharge are more likely to have labored breathing at rest but were not coughing more than control horses,² suggesting that cough and nasal discharge should be taken into account independently in the clinical assessment of horses.

Decreased Performance

A decrease in performance can be difficult to document reliably, notably because of the complexity of the variables involved. Optimal performance involves not only athletic and respiratory capacity, but depending on the disciplines, animal's skills can play a major role in the performance outcome. Measurements of performance are more often described in racing horses, with the analysis of variables like earnings, ranking, and number of starts, for example. Fitness and athletic capacity criteria are presented in the previous article (by Dr. L. Couëttil) of this in-depth series. Performance has been shown to be negatively affected in racehorses by exercise-induced pulmonary hemorrhage (EIPH),

as well as by inflammatory airway diseases (IADs). Willingness to perform is also affected in show jumpers and dressage horses affected with tracheal mucus accumulation.⁹ Decreased performance is one of the parameters included in the definition of the IAD phenotype.¹⁰

Labored Breathing at Rest

Labored breathing at rest is not specific of respiratory disease, but it is by definition a hallmark clinical sign of severe equine asthma (RAO).¹¹ Typically, horses with heaves will have a short inspiration but a prolonged biphasic expiration with an active abdominal lift, which can lead to hypertrophy of the abdominal oblique muscle (“heaves line”).¹²

Clinical Scores and Questionnaires

Some studies have used clinical questionnaires and performed association analysis based on the answers obtained from the owners.^{7,13,14} These questionnaires have been validated for the diagnosis of severe lung inflammation in RAO horses, but lack sensitivity and specificity for the detection of lower grade inflammation and IAD.⁷ The questionnaires give a total score for the horses based on the presence of respiratory clinical signs. Given that athletic horses present usually with more subtle clinical signs, the questionnaires are unlikely to be sensitive enough to detect respiratory problems in this population.

Based on the clinical signs and history, the clinicians can shortlist some working diagnoses and make a diagnostic plan. An interesting approach to decide on the choice of the most appropriate test and to interpret the results toward a diagnosis is the likelihood ratios (LR) and Bayes' theorem.¹⁵ Using this approach, after providing a pre-test probability of disease, clinicians can easily calculate a post-test probability at the animal level without taking into account the prevalence of the disease. The interpretation of test results using the LRs method is not affected by the prevalence of the disease, like it would be with the traditional approach using the positive or negative predictive values. The LR method is however based on the availability of the sensitivity and specificity of the ancillary diagnostic test to diagnose a respiratory pathology, as well as on the clinician's experience to estimate a pre-test probability of a horse having a pathology. Unfortunately, few studies have investigated the sensitivity and specificity of ancillary tests to diagnose respiratory diseases in horses. The choice of tests and interpretation of results is therefore mainly based on clinical experience.

2. Imaging Techniques to Diagnose Pulmonary Diseases in Athletic Horses

Endoscopy

This section describes the information available on the endoscopy of the trachea and lower airways. The upper airways (pharyngeal and laryngeal) en-

doscopy and scoring systems are outside the scope of this article. With the availability of more portable and affordable videoendoscopic equipment, it has become routine to perform endoscopy of the horses' airways.

Indications

Endoscopy of the trachea, tracheal septum, and bronchi provides valuable information in performance horses on the degree of mucus accumulation, inflammation, and to identify pulmonary bleeding. Lower-airway endoscopy is a sensitive test for detection of inflammation in the lower airway tract and specific scoring systems have been validated. Lower-airway endoscopy with scoring of the tracheobronchial blood has also been validated to assess the severity of EIPH.¹⁶

Equipment

Examination of the trachea can be performed with a 1.1-m-long endoscope, but the scoring and examination of the tracheal septum and main bronchi requires a 1.25–1.4-m-long endoscope. Longer 2–3-m gastroscopes can also be used to visualize higher generation bronchi and to perform a bronchoalveolar lavage (BAL; see the paragraph below).

Procedure

Sedation is often not necessary when a 1.2-m endoscope is used for a brief examination of the lower airways. Coughing during the endoscopy procedure is to be expected in horses with airway mucus accumulation or inflammation. Neuroleptanalgesia with butorphanol and local anesthesia with lidocaine instillation can be used to help prevent coughing and minimize patient discomfort.

Lower-Airways Nomenclature

Findings in the trachea and in the area of the tracheal septum are straightforward to describe anatomically, but a two-digit nomenclature system is often used to label the bronchi in the horse. Because horses' lung branches monopodially with smaller daughter bronchi branching from a main larger parent bronchus, the first nomenclature digit indicates the main bronchus (right, 1; left, 2) and the second digit indicates the secondary bronchus bifurcation location (for example, 1.3 refers to the third secondary bronchus in the right lung main bronchus).

Scoring of Mucus, Inflammation, and Blood Findings

Endoscopic scoring systems are available to quantify tracheal and bronchial mucus, tracheal septum thickness, and tracheal blood accumulation.^{16–18} Tracheal mucus score has been well validated using a 0 to 5 scale system. A score 0 represents absence of tracheal mucus, 1 is for multiple small blobs, 2 for larger blobs, 3 for confluent/stream-forming, 4 for pool-forming, and 5 for profuse amount of mucus.¹⁷

A similar scoring system has also been used for bronchial mucus scoring.¹⁸

Assessment of lower-airways mucus is not only for reporting purposes but has many practical clinical implications. Indeed, a mucus score ≥ 2 is associated with poor performance in Thoroughbred racehorses.¹⁹ Mucus accumulation can be secondary to inflammatory processes in the lungs, as well as a response to airborne dust.²⁰ In addition, the presence of mucus is correlated with neutrophil accumulation in the BAL.^{17,18}

Tracheal septum thickness at the level of the carina is not correlated with, and is not as clinically significant as, the tracheal mucus score. A greater tracheal septum thickness score is however consistent with a higher bronchial mucus score and is increased in horses with severe lung inflammation.¹⁸

The presence of blood in the lower airways is considered diagnostic of EIPH. Tracheal endoscopy has a high specificity for EIPH, but it is in the author's opinion highly dependent on the timing of the examination after exercise. It is generally recommended to perform a tracheal endoscopy 30 to 90 minutes after exercise to decrease the risk of obtaining false-negative results. Quantification of the tracheal blood has been proposed using a validated scoring system that uses a 0–4 grading scale. A grade 0 represents absence of blood, 1 is for at least one fleck of blood or short narrow streams of blood, 2 for one long stream of blood or more than two short streams occupying more than one third of the tracheal circumference, 3 for streams covering more than one third of tracheal circumference with no pooling, 4 for coalescing streams covering more than 90% of the tracheal surface with blood pooling.¹⁶ The correlation between tracheal blood grade and the amount of lung bleeding has yet to be established, but EIPH has been reported with a high prevalence in Thoroughbred and Standardbred racehorses as well as barrel racing horses.^{21–24}

Thoracic Ultrasonography

The lung is an air-filled organ and it may therefore seem at first that ultrasonography may not be the best diagnostic tool for performing a pulmonary examination. However, ultrasonography is diagnostically valuable and more sensitive than chest radiography for detecting pathologies affecting the lung periphery by identifying some lack of ventilation in the affected lung areas (shown by a breach in the normal reverberation artefact at the lung surface). The technique is simple and relatively quick to perform, does not require sedation and can also be performed without clipping the horse in most of the cases. The performance of the ultrasound equipment is continuously improving, now allowing identification of very minor lesions and therefore increasing the sensitivity of the technique. Caution should however be used to avoid over-interpretation of ultrasonography findings.

Ultrasonography can sensitively detect lung atelectasis or consolidation in the lung periphery. Thoracic ultrasonography can also reveal nonspecific abnormalities like pleural roughening and “comet tail” artifacts (also called B lines) but their severity remains a subjective assessment. M-mode ultrasonography can also be used to detect pneumothorax.

In racehorses, detection of the “comet tail” artifacts is a highly sensitive (89%), but not specific (26%) indicator of EIPH.²⁵

Altogether it is the author’s opinion that the thoracic ultrasonography is better suited for assessing infectious lung pathologies in athletic horses.

Lastly, recent developments in technology now allow performing endobronchial ultrasonography in horses, using a probe that is passed through the channel of an endoscope.²⁶ This technique has been shown to reliably assess airway smooth muscle mass in the main bronchi of horses and could be used to monitor airway remodeling and long-term response to therapy.

Radiography

Technique and Equipment

In practice, lung radiography is challenging to perform and interpret in horses because of the size of the animal. The distance between the horse body surface and the screen augments magnification and geometric distortion while decreasing image resolution. Four lateral views (dorsal and ventral caudal projections and dorsal and ventral cranial projections) should be used to evaluate the entire lung field in adult horses. Alignment of the generator with the cassette and the optional use of a grid make this technique extremely difficult to perform in general practice. The generator should be fixed and capable of >100 kVp and 30mAs. Exposure time should be kept as brief as possible. Exposure should be taken at the end of inspiration to decrease the degree of interstitial pattern.

Interpretation

Age, size, and respiratory phase should be taken into consideration when interpreting equine lung radiographs. Of the four radiographic lung patterns (interstitial, bronchial, alveolar, and vascular) the presence of bronchial and interstitial patterns suggest less severe of a pathology than does an alveolar pattern, and the latter is therefore not commonly seen in noninfectious lung diseases of athletic horses. Radiographic patterns correlate poorly with histologic lesions, and the localization of the abnormal patterns in the lung field is important. For example, interstitial lesions, and pulmonary edema are more commonly caudodorsal or diffuse.

A mild bronchointerstitial pattern should be interpreted with caution because it can usually be found in healthy racehorses and may be a result of subclinical peribronchial fibrosis.²⁷ In racehorses with pulmonary abscesses, lung radiography cou-

pled with assessment of blood parameters and other ancillary diagnostic tests can be used to predict prognosis for a return to performance.²⁸

Lung radiography has a poor sensitivity in detecting EIPH as many horses with EIPH have no radiographic lesions or have a nonspecific mild caudodorsal bronchial or interstitial patterns. Radiography may have some value in identifying severe cases of EIPH.

Some of the most chronic and severe RAO cases may have radiographic evidence of bronchiectasis, but in the case of athletic horses, thoracic radiographs are more often used to rule out pneumonia and are of limited benefit to diagnose nonseptic diffuse inflammatory lung diseases.²⁷

Scintigraphy

Nuclear scintigraphy has been used in research environments to study ventilation and ventilation-perfusion matching, as well as to study the efficiency of nebulizers.^{29–31} Nuclear scintigraphy has also been used to detect EIPH in racehorses and provides physiological information about the perfusion and ventilation of the caudal aspect of the lung in these horses.³² These techniques are not used routinely in practice and require safe collection of the aerosolized radioisotopes.

3. Sampling Techniques to Diagnose Pulmonary Diseases in Athletic Horses

Techniques used mainly for microbiology culture purposes are not specifically described here.

Sampling Tracheal Fluid for Cytology

Tracheal fluid cytology for the diagnosis of noninfectious inflammatory lung diseases is controversial. The cellular composition of airway secretions differs between the peripheral lower airways and the trachea and the true bronchiolar cytology is better represented in a BAL sample than in the tracheal wash fluid. Tracheal fluid is better suited for bacterial culture when pneumonia is suspected and a study found that almost five times as many positive cultures were obtained from tracheal fluid samples as were obtained from bronchial fluid.³³ The distinction between an infectious and a noninfectious condition can be difficult, and the developments in microbiome analysis may provide more information in the future about the relationship between lower airways microorganisms and inflammation.

The consensus definition of IAD and RAO is based on the use of BAL cytology to diagnose lung inflammation.^{10,11} In practice, however, tracheal fluid cytology is still commonly used in racehorses when the BAL cannot be performed for practical reasons. Tracheal fluid is usually collected by aspiration using a catheter passed through the working channel of an endoscope when performing a tracheal endoscopy in racehorses. It is recommended that the tracheal sample be collected after the horse has exercised to increase the chances of detecting airway inflammation or EIPH. Lastly, tracheal fluid cytol-

ogy can be challenging for the clinical pathologist because the cells from these samples can be quite degenerated and embedded in mucus.

Sampling Bronchoalveolar Fluid for Cytology

BAL is performed when the aim is to assess cellularity of the peripheral lower airways of the lung and is indicated for evaluating diffuse pathologies involving the small airways. A study revealing a good correlation between BAL cytology and lung histology³⁴ support the use of the BAL in that sense. However, others found some significant difference between BAL sampled in the right or left lung.³⁵ The BAL is a sensitive and reliable technique for detecting lung inflammation but attention needs to be paid to details like the volume of fluid infused during the procedure and the staining and counting techniques used at the laboratory.

Technique

The BAL can be performed in the field using a long tube (BAL tubes with a cuff at the tip) or under endoscopic guidance (ideally with a 2–3-m long endoscope). The key to the success of the procedure is to avoid coughing from the horse, as it compromises the wedge of the tube with the bronchus and affects dramatically the amount of fluid collected. To achieve this, a good neuroleptanalgesia is required (the author uses 10 mg of butorphanol combined with an alpha-2 agonist) and local anesthesia of the airways is also used (lidocaine diluted to 0.5%). The tube or endoscope progresses in the airways and usually is wedged in the caudo-dorsal lung area because of the monopodial anatomy of the bronchial tree in horses. There is a consensus that the BAL technique should use at least 250 mL of sterile saline for reliable results,¹⁰ and many research studies use two consecutive lavages. The fluid can be aspirated back with 60-mL syringes and transferred to ethylenediaminetetraacetic acid (EDTA) tubes and shipped to the laboratory with icepacks. It is important to submit samples to a laboratory with experience in BAL cytological analysis because of the particular cell staining and counting requirements.

Interpretation

The staining should allow an easy identification of mast cells and the Romanowsky, May-Grunwald Giemsa, toluidine blue, or modified Wright stains are recommended.³⁶ A Prussian blue staining technique can be used to identify hemosiderin more specifically.

The most reliable cell counting technique for the BAL differential analysis counts cells in five microscopic fields at 500× total magnification (50× objective and 10× eyepiece) on slides with high cell density.³⁷

The accepted reference values for the differential cell count in BAL fluid from healthy horses sampled with >250 mL of saline are as follows: Macrophages,

50–70%; lymphocytes, 30–50%; neutrophils, <5%; mast cells, <2%; and eosinophils, <0.1%.¹⁰

Depending on the horse populations and BAL volume infused, the neutrophils can often be found between 5% and 10% in horses that are deemed healthy.⁷ Horses with RAO have a moderate-to-severe BAL fluid neutrophilia, typically >25% and sometimes as high as >80%. Horses with IAD typically have a mild-to-moderate increase in neutrophil percentage, combined or not with an increase in mast cells and/or eosinophil percentage. It is common to also find giant cells, mucus, intracellular organic, and mineral particulates in the BAL from patients with lung inflammation. Before a diagnosis is made, it is very important to interpret with caution, and in light of clinical signs, a BAL cytological analysis revealing an increased percentage of inflammatory cells.

The BAL is also a reference technique to diagnose EIPH as it is more sensitive than the tracheal endoscopy and can detect red blood cells when no sign of bleeding is observed upon tracheal endoscopy.³⁸ Quantification of the severity of the EIPH episode by counting red blood cells in the BAL is not standardized yet. A benefit of the BAL technique for EIPH is that it provides information on the recent history of EIPH in horses by looking at the cell population of hemosiderophages. Indeed, the fact that the hemosiderophage count in BAL fluid remains high for 3 weeks after an episode of bleeding in mild EIPH can be used for clinical interpretation and management of these horses.³⁸

Lung Biopsy

The lung biopsy is a reference test for noninfectious lung pathologies and can be performed using a transthoracic approach. A spring-loaded automated needle system is recommended over a tru-cut system.³⁹ This technique provides excellent quality samples of small size for diffuse pathologies that affect peripheral lungs, but it presents risks to induce lung hemorrhage and pneumothorax.³⁹ The procedure should be performed in a hospital environment where critical care monitoring and blood transfusion are available. Another technique uses the endobronchial approach with forceps to take a deep piece of bronchial epithelium at various carinae under endoscopic guidance.^{40,41} This method is safer but provides even smaller and more superficial tissue samples than the transthoracic biopsy technique. It is used mainly for research purposes to quantify tissue expression of RNA and protein or to measure smooth muscle mass with morphometric analysis.

4. Lung Function Tests to Diagnose Pulmonary Diseases in Athletic Horses

This section briefly describes tests that are mostly available in a research environment. The most recent development in this area are the studies using VO₂max measurements in the field.

Lung Mechanics and Bronchoprovocation Tests

These techniques allow measuring the mechanical properties of the lungs, including the degree of resistance to airflow generally induced by a narrowing of the lower conducting airways. These techniques typically require the use of a facemask with a flowmeter and an esophageal balloon to measure pleural pressure. These techniques measuring standard lung mechanics at rest have been used extensively in equine research to assess the efficacy of various treatments for RAO where the bronchoconstriction is severe, but they are not sensitive enough to detect mild airway obstruction. Other techniques such as forced oscillation, impulse oscillometry, forced expiration, and volumetric capnography were adapted from human medicine to increase the sensitivity of detection of lung disease; however, these procedures may lack specificity and can be difficult to perform and interpret. Bronchoprovocation tests are used in horses suspected of having IAD, where the lung function is suspected to be abnormal despite the absence of clinical signs of labored breathing at rest. Horses with IAD will show marked bronchoconstriction at low histamine or methacholine concentrations, but these tests are also difficult to interpret and are not commonly performed in practice.

VO₂max Tests

Given that a small decrease in lung capacity has a dramatic effect in oxygen consumption during maximal intensity of exercise, measuring VO₂max may be a good way to detect early pathologies affecting the lungs of horse athletes. A decrease in VO₂max is however not specific of a lung pathology (as it can be affected by cardiovascular and lameness conditions) and requires a high-speed treadmill and specific flowmeters and gas analyzers. Portable prototypes of equipment allowing measuring VO₂max in field conditions have, however, recently been tested and may be promising in the near future to test the lung function of exercising horses.

5. Monitoring Response to Therapy

After a lung inflammatory pathology is diagnosed and recommendations are provided to the caretakers, it is useful to establish a plan for reassessment and monitoring of the condition. Obviously, clinical signs like coughing or the level of performance can be assessed by the owner, but other advanced tests are also available. The BAL provides some pertinent information about the status of the lung inflammation when management changes have been put in place. However, and interestingly, many studies found that the BAL cytology still shows an accumulation of inflammatory cells if the horses are treated with corticosteroids but without change in the air quality, whereas there is an improvement in the BAL cytology when the management is addressing environmental dust.⁴²⁻⁴⁵ The author will usually not repeat a BAL analysis for monitoring if a

treatment plan has not been in place for at least 6 weeks.

A bronchoprovocation test can be repeated for monitoring the respiratory condition if the technique is available; corticosteroid therapy will decrease airway hypersensitivity and hyperreactivity in 1 to 2 weeks after the treatment is initiated.⁸

In cases where the bronchoconstriction is severe and is recurrent like in horses with severe asthma, the airway remodeling is a concern because it could prevent a return to normal lung function despite a sound therapeutic plan. The reversibility of the bronchoconstriction can then be assessed by inducing a maximal short-duration bronchodilation and observing (or measuring) the improvement in respiratory function (corresponding to a decrease in lung resistance). Given that anticholinergic agents are more potent than β -adrenergic drugs to induce maximal bronchodilation in RAO, atropine, or *N*-Butylscopolammonium bromide can be injected intravenously while the horse's respiratory mechanics are recorded (or the effort of breathing is observed).^{46,47} Atropine has more adverse effects (tachycardia, mucosal dryness, colic, and excitation) than *N*-Butylscopolammonium bromide.⁴⁷

Clinical signs are often not reliable to monitor EIPH. Therefore, frequent assessment with tracheal endoscopy (30 to 90 minutes post racing) or a BAL cytology performed within a few days of racing are useful to detect episodes of EIPH.

6. Conclusion

Diagnosing pulmonary pathologies in athletic horses can be challenging and should start with a good documentation of the clinical signs. The interpretation of the ancillary tests can be difficult if a good technique and scoring systems are not used properly. In addition, athletic horses may have several pathologic conditions affecting different body systems altogether that add a level of complexity to the diagnostic plan. Although not discussed here, upper- and lower-airway pathologies are not uncommonly found together in the same horse, which will affect the therapeutic strategy.

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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.

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Therapy and Management of Equine Asthma

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1. Introduction

In considering both pharmaceutical therapy and management of equine asthma, it is important to establish reasonable goals for treatment. Although the goals in treating equine asthma are similar for both the recurrent airway obstruction (RAO) and inflammatory airway disease (IAD) subset, there are important differences in the reasonable expectation that the owner should have for return to athletic function. The goals for RAO should include: 1) immediate relief of the bronchospasm that causes cough and excessive respiratory effort, 2) reduction of lower airway inflammation, 3) long-term prevention of episodes of heaves by control of lower airway inflammation and airway obstruction, and 4) return to limited or even full athletic potential. The goals for treatment of IAD are similar: 1) eliminate cough and bronchoconstriction that impair performance, 2) reduce mucus production and airway plugging, 3) reduce airway reactivity, and 4) prevent recurrences.

General Approach: There must be a treatment strategy with recognizable and achievable goals in place that is approved by both the attending veterinarian and the owner or trainer in order for RAO or IAD to be treated successfully. Treatment of these diseases entails a team approach and an acceptance that this may be a life-long problem that may be

modified, but that is unlikely to go away. One of the most important aspects to successful treatment is establishment of a reasonable definition of return to athletic use. It is entirely reasonable to expect that a young racehorse would be able to return to racing after a short, targeted period of treatment. The owner of the older horse with heaves, however, must recognize that a much more modest return to light pleasure riding is a reasonable goal. The use of lung-function testing to assess response to bronchodilator therapy can be very useful in identifying horses that are less likely to respond to therapy.

Although it is important to assess the horse's immediate clinical presentation, it is equally important for both RAO and IAD to take an in-depth history to try to document environmental triggers. A very thorough inspection and assessment of the horse's environment is also critical to develop a plan to achieve environmental remediation. For instance, if the history suggests that the horse is consistently worse in the spring, whereas clinical signs are abated in the barn in the winter, it suggests that the worst culprits for this horse are the molds and pollens associated with moist warm weather, and the clinician may prescribe clean indoor living for the horse during that period. It is very useful for the owner or trainer to keep a

NOTES

diary for the affected horse, noting when exacerbations occur.

There is good evidence for the use of glucocorticoids and bronchodilators in heaves, and this knowledge has been extrapolated to the treatment of IAD. For both, the mainstay of treatment has become a combination of environmental remediation, corticosteroid therapy, and bronchodilators. In horses with RAO, there is evidence that the combination of these three approaches will give the best outcome.¹⁻³

2. Long-Term Control—Corticosteroid Therapy

Corticosteroids remain the cornerstone of successful treatment for both IAD and RAO. Inflammation underlies remodeling of the airways with accompanying airway hyper-reactivity, and consequent coughing and expiratory dyspnea. Bronchodilator drugs will help to relieve acute, debilitating bronchospasm, but only consistent anti-inflammatory therapy, in conjunction with avoidance of environmental triggers, will break the vicious cycle of inflammation, airway hyper-reactivity, and bronchoconstriction. The anti-inflammatory effect of corticosteroids in both RAO and IAD is impressive. Corticosteroids activate glucocorticoid receptors, thus putting into motion a profound inhibition of the arachidonic acid cascade and limiting production of leukotrienes and other inflammatory molecules. Response to steroids can vary considerably from horse to horse. A very important caveat, however, is that using corticosteroids without remediating the environment (see below) is like using hand sanitizer without washing your hands—better than nothing, but much less effective than removing the actual problem. In a study of stabled horses with heaves, treatment with dexamethasone failed to make a significant positive difference to the airway neutrophil counts in a subset of horses, indicating that corticosteroids cannot overcome environmental insult in all horses with RAO.² Moreover, a study found that although long-term corticosteroid treatment decreased airway smooth muscle in horses with RAO, airway neutrophilia persisted when horses were kept indoors.¹

Corticosteroids can be administered both systemically and via aerosolized delivery. Depending on the severity of disease, initial treatment may be systemic or a combination of systemic and aerosolized delivery and more chronic treatment may be aerosolized. The decision as to which delivery method is preferable may be influenced by a number of factors, including financial, given that aerosolized drugs and their delivery devices are quite expensive, as well as known and putative side effects. It is important to remember that corticosteroids can, among other things, adversely affect tissue growth and protein use, impair the barrier function of the intestinal mucosa, cause immune suppression, and suppress adrenal function.

Systemic Corticosteroids

Multiple studies have demonstrated the positive effects of corticosteroid drugs on horses with heaves, but the evidence for their use in IAD, despite good clinical response anecdotally, is less robust. Prednisolone and dexamethasone are the corticosteroids used most frequently in the treatment of RAO and IAD. Triamcinolone acetonide has also been shown to relieve airway obstruction in heaves.⁴ Triamcinolone, however, is anecdotally more closely associated with the development of laminitis in horses, than other corticosteroids. A recent study has shown profound and persistent hyperglycemia and hypertriglyceridemia (3–4 days) in horses after a single injection of triamcinolone, which may explain the anecdotal reports.⁵ Thus, its use is discouraged in the treatment of noninfectious inflammatory airway diseases. Prednisone was also frequently used in the past, but studies have shown therapeutic failures in heaves likely due to the horse's inability to absorb prednisone after oral administration.⁶ In a study looking at heaves-affected horses treated with either oral prednisolone (1.0 mg/kg bwt) or IM dexamethasone (0.1 mg/kg bwt) in conjunction with environmental control, both drugs had similar positive effects on the clinical signs of heaves, endoscopic scores, and blood gases. However, dexamethasone had a more beneficial effect on bronchoalveolar lavage (BAL) cytology.⁷ In a different study both prednisolone (2.0 mg/kg bwt, PO, once per day) and dexamethasone (0.05 mg/kg bwt, PO, once per day) improved pulmonary function, despite continuous antigen exposure. However, in that study oral dexamethasone was more effective than oral prednisolone in improving lung function in horses with heaves.⁸ A study also showed that horses suffering from heaves that were treated for 14 days with either isoflupredone acetate (0.03 mg/kg bwt, IM, once a day) or dexamethasone (0.04 mg/kg bwt, IV, once a day) all showed improvements in lung function, although BAL fluid samples were not assessed. Isoflupredone, however, resulted in hypokalemia, making it a less-than-optimal treatment.⁹

Inhaled Corticosteroids

The use of inhaled corticosteroids has truly revolutionized the treatment of RAO and IAD. Although initial systemic tapered corticosteroid therapy is often necessary with all but mild IAD, regular inhaled therapy is important for long-term success in many cases. The most important factor that limits regular use of inhaled corticosteroids is cost, because drugs such as fluticasone and beclomethasone, are very expensive. When assessing the effects of corticosteroids on horses with airway disease, it is important to note what delivery device and drug formulation was used because certain devices deliver more drug to the lower airways, and certain drug formulations, such as a proprietary formulation of beclomethasone^a, have been shown at least in humans to reach the lower airways more reliably.

For this reason it is very difficult, to make comparisons of drugs across studies that used different delivery devices. It is also important to remember that when comparing studies, the chlorofluorocarbon propellants that were used in older studies are not directly comparable to the currently used hydrofluoroalkanes (HFA).

Delivery Devices

There are several devices currently on the market for use in horses treated with pre-packaged aerosols (metered-dose inhalers [MDI]) include the Aerohippus^b and the EquineHaler^c. The choice as to which to use is largely determined by cost and which device will best suit the particular horse in question. A recent study compared the Aerohippus and the EquineHaler using a pressurized MDI and HFA-albuterol to elicit bronchodilation in horses with bronchospasm associated with exacerbation of heaves.¹⁰ There was no statistical difference in the decrease in pulmonary resistance produced by albuterol administered using the two different devices; however, there was a more consistent response with the Aerohippus and a study using the prototype for the Aerohippus showed superior delivery of a radio-labeled substance to the lower airways compared with the manufacturer's data for the EquineHaler.¹¹ Regardless of the type of mask/spacer device used, actual delivery of particles to the lower airways is poor in the horse, given that indeed it is even in humans, and the least efficacious means of delivering aerosolized drugs is by jet nebulizer. Unfortunately, strategies that we know improve lung deposition of aerosolized drugs in humans, such as slow deep breathing and breath holding, are not practical in the horse. For the competition horse it is important to remember that, even though deposition of aerosolized drugs in horses is poor compared with that in humans, residues may still be found in horse's blood and urine, leading to the possibility of the horse testing positive for the substance, given that has been found with therapeutically delivered doses of fluticasone propionate.¹²

Side Effects

Aerosolized corticosteroids are frequently preferred over systemic in order to decrease potential side effects. This is well documented in humans, but while this is a rational approach in horses, there is little documentation to support it. However, using the Aeromask and fluticasone propionate at a dose of 2000 μ g twice daily, heaves-affected horses were shown to have significant improvement in clinical signs and lung function and immune responses were still intact.¹³ In contrast, a single 0.025 mg/kg bwt dose of dexamethasone given IV decreased total lymphocyte counts in horses. Although there is evidence of hypothalamic-pituitary-adrenal axis (HPA) suppression with all clinically relevant doses of beclomethasone, this does not seem to pose a risk of chronic HPA suppression or Addisonian crisis.¹⁴

Likewise, inhaled fluticasone propionate (1500 μ g every 12 hours) may cause significant decreases in serum cortisol after 7 days.¹⁵ Thus, inhaled corticosteroids certainly have systemic effects; the hope is that these effects will be less profound than with systemic therapy.

Efficacy of Inhaled Corticosteroids in Horses

When comparing the potency of inhaled corticosteroids, we are obliged to look at our favorite lab animal, the human, given that no real comparative studies have been done in horses. Fluticasone propionate is thought to be the most potent, has the longest pulmonary residence time, and causes the least adrenal suppression. In contrast, newer formulations of beclomethasone dipropionate that incorporate HFA as the propellant have more uniform particle size, and are more uniformly mixed, requiring little to no agitation or waiting before actuation of the inhaler. Fluticasone propionate resulted in complete resolution of clinical signs in horses with exacerbation of heaves, as well as normalization of pulmonary function tests and significant decrease in BAL neutrophilia. In humans, there is less systemic absorption of fluticasone, but it is not known whether this is true in horses. In our clinic, we use both inhaled beclomethasone dipropionate^a and inhaled fluticasone propionate^d and the deciding factor as to which one is used is often the cost. For reasons that are not well understood, some horses seem to do better on one drug than the other, and the clinician must maintain a certain flexibility in choosing drugs. In our clinic, we frequently treat with an initial course of parenteral corticosteroids, typically, a 4-week, decreasing course of prednisolone, followed by inhaled corticosteroids.

3. Long-Term Control—Bronchodilator Therapy

As with corticosteroids, bronchodilators can be administered both systemically and via aerosol; however, aerosolization is by far the preferred method because it minimizes side effects. Bronchodilators generally fall into one of two categories: either beta-2 agonists (B2-ARs) (sympathomimetics) or parasympatholytics. Of the B2-ARs commonly used in equine medicine, albuterol, which is known as salbutamol everywhere but in the United States, is primarily administered by inhalation, and clenbuterol is administered orally. For the parasympatholytic agents ipratropium is administered by inhalation and hyoscine butylbromide^e is administered parenterally.

In addition to bronchodilation in horses experiencing bronchoconstriction, B2-ARs also cause epitheliated cilia in the airways to beat faster and with greater coordination. There is also some evidence that B2-ARs suppress airway mucus production. A lesser but potentially useful action of B2-ARs, is inhibition of release of inflammatory mediators from cells, such as neutrophils.

Systemic Bronchodilator Therapy

Clenbuterol^f is a B2-AR that was approved for use in horses in the United States in 1998. In addition to its use as a bronchodilator, clenbuterol has tocolytic effects in both women and animals, and has a profound repartitioning effect in muscle, although the mechanism of this latter effect is poorly understood. Practitioners should be aware that reports of severe toxicity in horses given improperly compounded formulations of clenbuterol have emerged.¹⁶ The safety and efficacy of chronic administration of even the US Food and Drug Administration-approved formulation of clenbuterol is controversial. Chronic administration of clenbuterol at 2.4 $\mu\text{g}/\text{kg}$ (5 days on, 2 days off, for 8 weeks) was reported to have a negative effect on aerobic performance in horses; however, a recent study reported that no negative effects on equine cardiac or skeletal muscle were seen when clenbuterol was administered at up to 3.2 $\mu\text{g}/\text{kg}$ bwt, PO, daily for 14 days.^{16,17} Tachyphylaxis also seems to be a problem with chronic administration of clenbuterol. For example, a recent study demonstrated that after 3 weeks of clenbuterol administration at 0.8 $\mu\text{g}/\text{kg}$ bwt, PO, every 12 hours increased airway reactivity was evident and the horses were refractory to the bronchodilatory effects of clenbuterol.¹⁸

Reports of the efficacy of clenbuterol are also conflicting. A large study by Erichsen et al¹⁹ showed that 25% of horses had a decrease in clinical signs of heaves when treated with clenbuterol at a dose of 0.8 $\mu\text{g}/\text{kg}$ bwt, but a second study failed to show any benefit on clinical signs when a similar dose was administered.^{19,20} Most horses seem to tolerate the lower doses of clenbuterol well, but with higher doses horses may have, among other signs, tremors, tachycardia, sweating, and an appearance of anxiousness. Together, these findings suggest that the practice of administering clenbuterol to horses to enhance performance is probably misguided at best, and harmful at worst. It is also important to recognize that the recommended duration of treatment is 30 days. Clenbuterol is not appropriate and should not be used as a chronic therapy.

Cautions

Clenbuterol should be avoided in horses with cardiac disease, given that it can cause tachycardia and in pregnant mares, given that it antagonizes the effects of oxytocin and prostaglandin F₂ α (PGF₂ α).

Short-Acting Inhaled B2-ARs Therapy

These agents, such as albuterol and fenoterol, are of vital importance in treatment of acute exacerbations of RAO. Albuterol is recognized universally as a rescue drug for both human asthmatics and horses with IAD/RAO. Horses with current exacerbations of RAO labor to breathe and experience paroxysmal coughing; within 10–30 minutes after aerosolized delivery of albuterol they will experience significant relief. However, the effect wears off within 1–3

hours. It is important to remember that the inflammatory condition will persist despite apparent improvement due to transient bronchodilation, and the disease will worsen. Regular use of B2 agonists in the absence of anti-inflammatory medication may mask symptoms that would otherwise indicate progressive worsening of the disease in particular, further airway obstruction with mucus. However, use of aerosolized albuterol for 10 days seemed not to affect airway reactivity.¹¹ Albuterol is the most affordable of the short-acting B2 agonists; however, levalbuterol^g, the R-enantiomer of albuterol, has recently become more affordable. Albuterol is thought to cause bronchoconstriction in some asthmatics, and there are *in vitro* reports to suggest that it may do so in horse airways as well²¹; this adverse event may be avoided with the use of levalbuterol. Recently, levalbuterol was shown to produce bronchodilation for 120 minutes vs 60 minutes for albuterol in horses with RAO.²²

The preponderance of evidence shows that short-acting B2 agonists are not performance enhancing in humans, and there is no evidence to suggest that they are performance enhancing in horses. Nonetheless, all equine sporting events ban albuterol, and due care should be taken to stop drug administration before competition, noting that albuterol can be detected in urine for at least 48 hours after administration via metered dose inhaler. Short-acting B2 agonists can be useful in horses with RAO and underlying airway obstruction to improve the return to training. Short-acting bronchodilators are also useful during lung-function testing to assess the reversibility of airway obstruction in horses with RAO. No more than 450 μg of albuterol by inhalation using MDI is necessary to bronchodilate most horses, irrespective of the delivery device chosen.

Although aerosolized B2 agonists have a relatively low incidence of side effects, excessive use or sensitive individuals may experience systemic effects such as trembling, anxiety and cardiac arrhythmias. The author has noted all these in individuals treated with 900 μg of albuterol, whereas other individuals show no signs of intolerance. Repeated use of the drug tends to decrease side effects as the body down-regulates receptors. Very occasionally, horses may exhibit signs of bronchoconstriction following administration of B2 agonists. This paradoxical response is likely due to the effects of the drug vehicle on airways and is usually transient.

Long-Acting Inhaled B2-ARs Therapy

We treat selected cases of RAO and moderate IAD with long-acting B2-ARs therapy in addition to inhaled corticosteroids, with the initial impression of enhanced performance and quality of life. It cannot be emphasized enough, however, that regular use of long-acting B2-ARs must be accompanied with regular use of inhaled corticosteroids. The

most commonly used long-acting B₂-ARs are salmeterol and formoterol. Their duration of action in horses is 6–8 hours.

Inhaled Parasympatholytic Therapy

The most commonly used inhaled parasympatholytic drug is ipratropium, a quaternary ammonium derivative of atropine; which produces bronchodilation lasting approximately 6 hours, which is at least 3 hours longer than albuterol.²³ Although adverse side effects such as thickened mucus, tachycardia, and decreased ciliary beat frequency are possible with parasympatholytics, no such side effects have been reported in horses administered doses up to 1200 µg. Ipratropium cannot be considered a rescue drug, unlike atropine, because it has much longer onset of action; however, the effect may last somewhat longer than atropine. In severely affected RAO horses, the combination of albuterol and ipratropium may be beneficial.

Mast-Cell Stabilizers

These agents are cromones that block calcium channels preventing the release of histamine and tryptase, and the subsequent downstream cascade of prostaglandin and leukotriene formulation that eventually cause bronchoconstriction. Sodium cromoglycate can be efficacious in treating known mast cell-mediated IAD, but will not be of use for treating the majority of horses with neutrophil-mediated disease, and therefore they are less useful for RAO. It should be noted that the best evidence for their use is quite old.²⁴ Moreover, use of mast cell stabilizers requires considerable owner compliance, given that the maximum response to these drugs occurs at 1–2 weeks after beginning treatment.

Other Therapeutic Approaches

There are, unfortunately, few pharmacologic treatments with proved efficacy other than corticosteroids and bronchodilators. A recent approach taken involved the attempt to shift the Th1/Th2 immunologic balance by administering inhaled nanoparticles of cytosine-phosphate-tuanosine oligonucleotides, which did result in some promising outcomes including decreases in tracheal wash neutrophils and improved lung function and clinical scores.²⁵ Curcumin, which comes from the spice turmeric, and has been shown to be efficacious in pulmonary fibrosis and asthma in humans, has also been used in horses with RAO by decreasing the cellularity of the BAL fluid.²⁶ Finally, although earlier studies using sunflower oil and sealblubber as a source showed no efficacy of omega-3 fatty acids in ameliorating signs of RAO, a recent study using docosahexaenoic acid in addition to a low-dust environment did significantly improve clinical signs in horses with RAO.²⁷

Cell-Based Therapy

The most recent and intriguing approach to equine asthma is the use of cell-based therapies. A recent

in vitro study used lipopolysaccharide (LPS)-treated equine alveolar macrophages as a model for equine asthma. They treated these cells with conditioned medium from amniotic mesenchymal cells to determine whether the conditioned medium was able to ameliorate the effect of the inflammatory cytokines that resulted from LPS treatment. Their most significant finding was that the conditioned medium did indeed decrease the production of TNF-α from the alveolar macrophages.²⁸ This approach certainly warrants further investigation.

4. Environmental Remediation

It is important to note that a recent study demonstrated that environmental control was by far the most important means of treating airway inflammation and dysfunction in horses with heaves, and that, indeed, antigen avoidance decreases airway smooth muscle mass.¹ The barn environment is replete with organic particulate matter, respirable endotoxin, molds, and volatile gases such as ammonia. The worst offenders seem to be hay and straw. Multiple studies have shown that significant improvements can be made by replacing dusty substrates and feed with less dusty substitutes. For instance, pelleted hay and wood shavings are often better than regular hay and straw bedding.^{29,30} Indoor arenas present another high dust challenge to the horse, but good management can mitigate the problem.³¹ In addition to changing to low-dust feeds and beddings, the following recommendations to owners should be made:

- Feed hay from the ground, not from a hay net
- Soak hay well before feeding or use ensiled or baked hay products
- Wet any dusty grain (e.g., pellets) before feeding
- Sprinkle aiseways with water before sweeping
- Avoid storing hay overhead. If unavoidable, lay a tarp under the hay to avoid dust raining down on the horses
- Use a humectant or hygroscopic agent to reduce dust in the indoor and outdoor arenas
- Remove horses from the barn while cleaning stalls or moving hay
- Do not use blowers to clean aisles
- Remove cobwebs and other dust collectors routinely when horses are of the barn
- Keep barn doors open to promote good ventilation

An overarching principle that can be derived from the US Occupational Safety and Health Administration Dust Control Handbook is that prevention is better than cure. In addition to the well-known presentation of summer pasture-associated recurrent airway obstruction in hot, humid southern states, it is important to remember that horses in New England can also have disease that presents primarily in the spring and summer, and that seems

to improve when horses are kept temporarily in clean, nondusty indoor environments. A recent study in the northern hemisphere confirmed that environmental heat and airborne pollens are both associated with an increase in severity in equine asthma signs.³²

5. Evaluation of Therapeutic Outcome

It is important to have a baseline assessment of the horse prior to initiating therapy. Ideally, this would include auscultation with and without a rebreathing bag, careful physical examination, observation during exercise, BAL, and baseline pulmonary function testing for horses with IAD and RAO and measurement of airway reactivity for horses suffering from IAD or in the case of horses with RAO, post-bronchodilator pulmonary function tests. Although historically pulmonary function testing was available only at a few specialized veterinary pulmonology clinics, user-friendly systems for field testing are now available, making objective baseline assessments possible for practitioners. The goal of a thorough baseline assessment is to facilitate a treatment regimen tailored to the individual horse, and to monitor response to therapy. Horses should then be evaluated 1–2 months after initiation of therapy to assess response and guide therapy for the upcoming months. If there is poor response to therapy, it is important to do some detective work to determine why treatment has been unsuccessful. For example, it is essential to check the client's technique for using the drug delivery device. Failure to modify the environment may, in some horses, negate any attempts at drug therapy. Some horses with chronic, severe pathology may be resistant to corticosteroids or may have irreversible changes in the lungs that prevent response to bronchodilators. Finally, lack of response to therapy may be due to underlying infectious disease and may indicate the need for further diagnostics and perhaps an entirely different approach or concomitant antibiotic use.

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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- ^cEquineHaler, Equine HealthCare, Horsolm, Denmark.
- ^dFlovent, GlaxoSmithKline, Brentford, United Kingdom.
- ^eBuscopan, Boehringer-Ingelheim Vetmedica, Inc., St. Joseph, MO 64506.
- ^fVentipulmin, Boehringer-Ingelheim Vetmedica, Inc., St. Joseph, MO 64506.
- ^gXopenex, HFA Sunovian Pharmaceuticals, Marlboro, MA 01752.

Understanding and Implementing Principles of Learning in the Equine Veterinary Practice

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1. Introduction

Veterinarians who work with horses have a higher risk of serious injury than firefighters, police officers, and other civilian occupations, according to a recent study in the United Kingdom.¹ Equine veterinarians suffer approximately eight injuries over their career, and the primary cause is from a kick or strike by the horse. Behavior problems during veterinary care are common; a horse that is unfamiliar with a veterinary procedure, has had a negative experience, or is frightened or injured can take longer to examine and cause a great deal of damage. Practices that reduce behavior problems in the horse will help mitigate the risk of injury to veterinarians.

A limited understanding of learning principles and science-based behavior modification techniques may be linked to the high incidence of injury.² A survey of veterinarians in the United Kingdom found that most lacked education about and did not use methods based on learning principles and science-based behavior modification methods; instead, dangerous situations were generally managed with chemical or physical restraint. Although necessary in some situations, restraint can provoke even more dangerous escape responses and does little to resolve behavior problems, which

requires addressing the horse's emotional state and the environment.

Handling methods that promote calm emotions and prevent stress, anxiety, and fear are recommended by the American Veterinary Society of Animal Behavior.³ Positive veterinary care practices can increase caregiver safety and animal welfare,⁴ as well as improve diagnosis and treatment outcomes; when a patient becomes fearful or anxious during an exam, sympathetic arousal can interfere with accurate diagnosis.³ Even pain-free procedures can cause discomfort if the animal is tense, or if punishment and restraint are used to control behavior. Fear and anxiety negatively affect future health care as well; even one unpleasant veterinary experience can generalize to subsequent visits, and when an animal has a history of fear and behavior problems the owner is less likely to call the veterinarian.

The use of behavior modification techniques based on principles of learning can reduce fear and problem behaviors^{5,6} and promote positive veterinary care.⁴ Low-stress handling and nonaversive behavior modification methods have been widely adopted among veterinary professionals who work with small animals^{4,6} and large captive land and marine mammals.^{7,8} Similar strategies can be ap-

NOTES

plied to horses to improve caregiver safety, health care efficiency and outcomes, as well as animal welfare.^{5,9} In fact, it can be reasonably argued that maintaining positive interaction is even more important for larger and potentially more dangerous species. The following sections describe positive methods based on well-tested, scientifically sound principles of learning and behavior modification and their application in equine veterinary practice.

The Cycle of Anxiety and Avoidance: How Horses Learn to Misbehave

Fear and anxiety are the root cause of behavior problems with veterinary care, including not standing still for examination; barging or pushing; reluctance to enter the exam room, stocks or trailers; bolting or pulling away when led; and biting, kicking, or striking. These behaviors are often inadvertently reinforced by the release of pressure (negative reinforcement) and will be repeated. Anxiety often begins with normal wariness about an unfamiliar object or situation. If the horse then also experiences stress or pain, it will learn to anticipate the object or situation as a potential threat, and also learn to fear anything associated with it, a process called fear conditioning. Horses, as a prey species, are especially adept at this type of learning. In veterinary care, things associated with an unpleasant procedure might include the location, veterinarian, or equipment. For example, a horse that experiences distress or discomfort during an injection may become anxious simply at the sight of the syringe because it is reliably associated with the injection.

Individual horses respond differently to various stressful situations and levels of discomfort. Most cope with aversive conditions well, but others show extreme reactions. On one extreme are horses that shut down and withdraw; on the other extreme are horses that attempt to escape, and if prevented from doing so, may become aggressive. Fear-based defensive aggressive responses are dangerous; they almost always remove, terminate, or postpone the procedure, if only briefly, and are thus inadvertently reinforced and will be repeated. The cycle of anxiety and avoidance (Fig. 1) will persist if a horse is put back into the same situation in which the fear and problem behavior previously occurred.

Managing behavior problems with punishment and/or increased physical restraint is more likely to escalate than to break the cycle of anxiety and avoidance. Punishment and physical restraint add to the horse's discomfort and anxiety. Restraining devices, such as a lip or ear twitch, stud chain, or antirearing bit, are conventionally used to control the horse's behavior during veterinary care.¹ It is also common practice to punish unwanted behavior by jerking on a halter or chain, waving a whip or rope, striking the horse, or yelling sharply, despite recommendations against the use

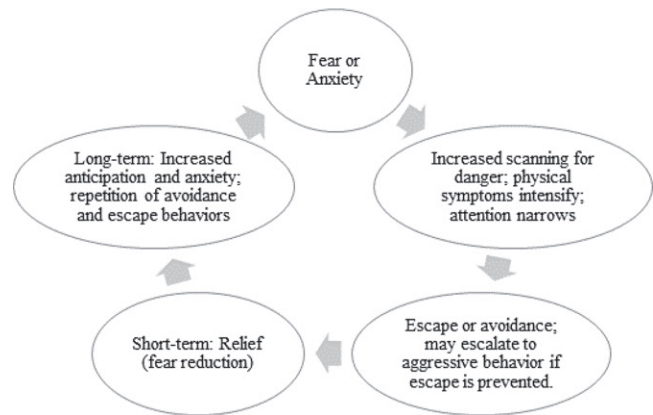


Fig. 1. The cycle of anxiety and avoidance.

of punishment by the American Veterinary Society of Animal Behaviorists.¹⁰

Behavior Modification: Preventing and Reversing Problems

The goal of behavior modification in veterinary care is to reduce both the underlying fear and unwanted behavior, as well as to strengthen positive emotions and compliance. A behavior analysis of the problem helps identify learned causes as well as other possible contributing factors such as physical pain, neurological and metabolic conditions, and infectious disease.⁵ Identifying the reasons for the fear and anxiety is an important first step, and behavior can be improved by eliminating or treating them. When a learned cause is suspected, evidence-based behavior modification techniques can help meet behavior-change goals.^{4,5,9,11} Selected techniques particularly useful to veterinarians who work with horses are described in the following sections.

2. Monitoring for Relaxation and Recognizing Early Signs of Fear and Anxiety

Maximizing a calm emotional state and minimizing fear and arousal requires keeping the horse as calm as possible, and monitoring body language for relaxation and early signs of anxiety. When a horse is relaxed, unwanted behaviors are less likely to occur, and the long-term effectiveness of behavior modification is improved. Animals learn best at mild to moderate levels of sympathetic arousal—when they show attention, without tension; at higher levels of arousal the brain is primed for defensive action and fear conditioning. A horse's facial expressions,¹² posture, and muscle tension offer a window into its internal emotional state and provide a tool for assessing the animal's level of arousal, anxiety, and attention (Fig. 2).^{13,14}

3. Creating a Relaxing Environment

A familiar axiom among behaviorists is “the ABC’s of learning,” which is an abbreviation for antecedents, behavior, and consequences. Arranging ante-

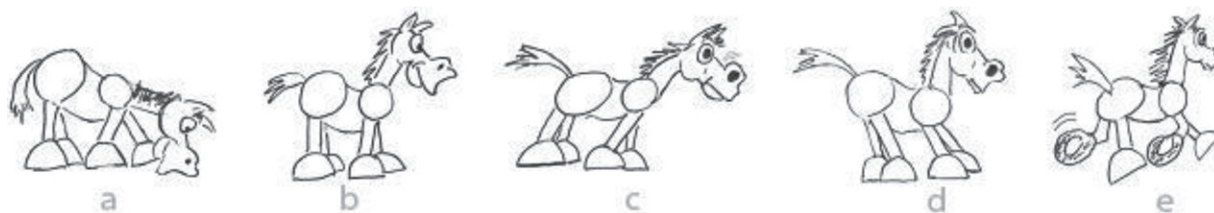


Fig. 2. A cartoon illustration of the equine defensive action sequence. Responses having low arousal and low perceived threat are on the left, with increasing arousal and greater perceived danger on the right. Response categories include (a) relaxation, (b) attention, (c) tension (d), avoidance, and (e) flight.

cedents is a powerful and effective strategy for maintaining an animal's positive emotions and calm demeanor. Antecedents refer to any cues in the environment that predict whether something pleasant or threatening might occur, or if a response will be rewarded or punished. If the experience is repeated, the horse learns to anticipate the event and will start to react sooner, in response to these antecedent cues.

Horses often react to cues associated with veterinary care because they are distinctive, ritualized, and predictable. The horse is led to a particular location where the procedure takes place, an ambulatory veterinarian truck is parked nearby, the veterinarian sets up special equipment, and the exam is carried out in a fixed order. This means that a horse can readily learn to anticipate a veterinary visit and respond long before the exam or procedure begins. Previously neutral objects will elicit fear if they have been associated with pain or discomfort, and through the process of generalization, other similar stimuli can also begin to elicit fear, anxiety, and problem behaviors. Alternatively, creating a positive association with the veterinary experience promotes calm emotions and behavior.

The location where the veterinary exam takes place is a common trigger for anxiety if a bad experience previously occurred in that area. The horse may be more relaxed if the exam is conducted in a different location, particularly one previously associated with positive experiences. Conducting procedures in a quiet environment with few distractions, minimizing noises linked to specific procedures—for example, by using silent clippers—and limiting the use of bright lights, are recommended.⁶ Emotional states are socially facilitated (contagious) in horses, so having a relaxed, familiar horse nearby can help calm some nervous horses. Conducting veterinary exams or procedures in the horse's stall is not recommended; this area should be reserved as a sanctuary or "safe zone" where nothing unpleasant happens.

If a horse is overly fearful or anxious, or if its behavior is dangerous, the veterinary exam can be broken up into multiple visits, and nonessential procedures postponed for a later time.⁶ In some cases, anxiety-reducing medications and products can im-

prove behavior in the moment, as well as increase the effectiveness of behavior modification.

4. Habituation and Systematic Acclimation to Novel Objects and Situations

The initial veterinary experience can have a profound and lasting effect on future behavior. At this time, the horse's reactions to unfamiliar people, situations, sensations, and equipment are unlearned and automatic. Habituating the horse to being handled and examined is an important goal of positive veterinary care. Habituation refers to a decrease in the strength of a response with repeated exposure to the object or experience, and will occur if a situation is nonthreatening. Potentially fear-inducing novel objects, situations, or mildly aversive veterinary procedures can be introduced gradually through the process of systematic acclimation.

If the potentially threatening situation is too strong, persists, or intensifies, then sensitization might occur; the horse's senses become heightened and skeletal muscles mobilize for defensive action. In horses, defensive behaviors escalate in a predictable action sequence that includes orient, freeze, fidget, avoid, flee, and fight (Fig. 2). The sequence reflects increasing sympathetic arousal and cognitive capacity for fear conditioning. Sensitization can be avoided by monitoring body language and arranging the situation to reduce levels of arousal and anxiety, but prevention is the best medicine. Taking a proactive approach with young horses by providing positive, mildly stressful experiences will help build resilience to veterinary handling, equipment, and procedures.

5. Reducing Fear and Problem Behaviors with Systematic Desensitization

Systematic desensitization works to overcome a horse's learned fear of an otherwise-harmless object or situation through gradual, progressive exposure to the feared stimulus. The stimulus is presented at a low intensity and/or short duration, while the horse remains calm and without triggering fear or defensive behavior. Through repeated nonthreatening experiences, the negative emotions and problematic behavior decrease. The intensity and duration of exposure to the feared object or situation

is gradually increased, typically over multiple sessions, and if the horse should display stress-related or defensive behaviors at any time during the process, the intensity and duration of exposure is reduced. Systematic desensitization is often combined with relaxation techniques and counterconditioning.

6. Counterconditioning

Counterconditioning is a treatment for phobias and conditioned fears in which the individual learns an incompatible response when presented with the feared but otherwise-harmless stimulus. It works by creating a new association between the feared stimulus and a pleasant stimulus. The pleasant stimulus elicits a positive emotion and relaxed response, which replaces the fear and withdrawal behaviors. After repeated pairings between the feared and pleasant stimuli, the previously feared stimulus comes to predict a rewarding rather than an unpleasant event. In practice, counterconditioning is typically used in conjunction with gradual exposure to the feared stimulus (systematic desensitization).

Counterconditioning can be applied broadly to veterinary handling, procedures, restraints, and equipment.⁴ For example, a horse with a learned fear of injections may withdraw from the syringe by becoming tense, raising its head, and stepping backward. Although the syringe is harmless, it has become aversive through past association with a distressing or painful experience. During counterconditioning, the syringe would be paired with and predict something pleasant, like a treat placed in a dish on the ground, such that when the syringe is presented, the horse remains calm, drops its head, and takes a step forward for the treat. Calm emotions and head dropping thus become the horse's newly conditioned response to the syringe.

By definition, counterconditioning is a classical conditioning process that involves pairing the feared stimulus and the pleasant stimulus at the same time. For example, with a needle-shy horse the syringe (the feared stimulus) might be held against the horse's neck for 10 seconds, and at the same time the horse would get treats (the pleasant stimulus). The treats would stop when the syringe is removed. A recent study found, however, that a modified counterconditioning technique was more effective and resulted in a lower risk of relapse; the modified technique involves first presenting the feared stimulus, and then offering the reward only after the animal performs a desired behavior.¹⁵ For example, modified counterconditioning could be used in a needle-shy horse. The syringe would be held against the horse's neck for 10 seconds, and treats presented only if the horse stands calmly (the desired behavior).

Distraction with pleasurable activities can also help to promote relaxation by shifting the horse's attention away from the veterinary procedure.

Engaging the horse in a previously trained, familiar, positively reinforced task such as touching its nose to a target for a treat reward¹⁶ will divide attention, reduce stress, and create a positive association with the veterinary procedure. Scratches or massage are relaxation techniques that can also be used as distracting activities.¹⁷ For example, a gelding scratched on the belly with a stiff brush when his hoof was trimmed immediately stopped fidgeting and pulling his leg away. Pharmacological agents and supplements such as calming pheromones or a sedative administered orally or rectally can also help reduce anxiety before veterinary procedures.

7. Overshadowing

Overshadowing¹⁸ is a technique used to attenuate fear and related problem behaviors that can be applied to horses. The horse is lead forward with determination, as if going somewhere, or back and forth a few steps using forward and reverse rein cue, and at the same time the feared stimulus is introduced. The horse should be first trained to step forward and backward on light rein pressure. The movement of the horse distinguishes overshadowing from other exposure methods for reducing fear-based problem behaviors.

Overshadowing has been used in veterinary care on horses that are fearful during injections and when clipped. Reports about its effectiveness at reducing problem behaviors and decreasing sympathetic arousal have been primarily anecdotal, and empirical confirmation is lacking. Whether overshadowing works via habituation, desensitization, flooding, or some other mechanism is not clear. Restraining devices, such as an anti-rearing bit, are often used to direct the horse's movement and simultaneously prevent unwanted responses. Because the horse is moving forward or stepping back and forth while being injected or clipped, implementing overshadowing requires a skilled handler to avoid flooding.

8. Avoid Flooding

Flooding refers to exposing the horse to a high intensity of the feared object or situation until the unwanted response disappears. At the same time, the horse is typically confined or restrained to prevent it from escaping or even performing the problem behavior. One example of flooding would be a horse with fear of hoof trimming and severely overgrown feet who is placed in stocks with its hoof securely tied up with rope (response prevention) to use an angle grinder on it (high intensity of the feared stimulus). It is called flooding because the horse is overexposed to the feared stimulus and "flooded" with fear and anxiety. In theory, flooding should lead to extinction of the fear and defensive behavior, and break the cycle of anxiety and avoidance. In practice, flooding is distressing or even traumatic, leads to behaviors that are unsafe for both horse and caretaker, and can worsen the fear

Table 1. The Four Quadrants of Operant Conditioning

	Reinforcement Increases Behavior	Punishment Stops Behavior
Positive (+) Something is added	R+Positive Reinforcement <i>Behavior increases because it results in something pleasant being added.</i> <i>Example: The horse drops his head because he gets scratched on the neck or withers.</i>	P+Positive Punishment <i>Behavior stops because it results in something unpleasant being added.</i> <i>Example: The horse stops raising his head because the lead rope is yanked sharply.</i>
Negative (-) Something is removed	R-Negative Reinforcement <i>Behavior increases because it results in something unpleasant being removed.</i> <i>Example: The horse turns her hindquarters away from the veterinarian because it delays having the rectal thermometer inserted.</i>	P-Negative Punishment <i>Behavior stops because it results in something pleasant being removed.</i> <i>Example: The horse stops pawing at the ground because she is ignored and does not get the attention she seeks.</i>

Operant conditioning refers to voluntary behavior that is shaped by its consequences, which are pleasant, unpleasant, or neutral. Reinforcement refers to behavior that leads to pleasant consequences and is repeated in the future, whereas punishment refers to behavior that leads to unpleasant consequences and is inhibited in the future. An animal's actions also add or remove something from the environment. When something is added the mathematical notation "positive" is used, and when something is removed or subtracted the mathematical notation "negative" is used. This table is the definition and example of each of the four quadrants of operant conditioning (positive reinforcement, negative reinforcement, positive punishment, and negative punishment).

and problem behavior, especially if the horse breaks free from the restraint. The use of flooding in equine veterinary care and training is not recommended.^{5,18}

9. Reinforce Desired Behaviors and Avoid Reinforcing Unwanted Behavior

Strengthening desired behaviors and decreasing problem behaviors using operant conditioning often calls for a two-pronged strategy. One prong involves positively reinforcing (Table 1) desired behavior, such as standing calmly or offering a hoof. Sometimes the desired behavior must be shaped first, by progressively rewarding closer and closer approximations of the goal behavior. The second prong is to stop reinforcing problem behaviors, which often persist because they are accidentally reinforced. Any behavior that delays a procedure, even briefly, will be negatively reinforced (release of pressure; Table 1) and repeated in the future. Ideally the environment has already been set up to minimize fear and problem behaviors, but it is important to be prepared if they occur.

The needle-shy horse offers a useful example of how the two prongs of differential reinforcement can be applied. A needle-shy horse often barges forward as the veterinarian approaches with a syringe in hand. When the person takes a step back to get of the way, the barging behavior is reinforced because the horse gains some distance from the feared syringe and delays the injection. Instead, the person should keep the syringe in a constant position, moving with the horse as it steps forward, and then remove the syringe only after the horse stops moving. Doing this will reinforce the desired behavior of standing still, but not the unwanted behavior of moving away. This example incorporates two effective strategies. First, the reinforced calm behavior,

standing still, cannot occur at the same time as the problem behavior, barging forward; this procedure is called differential reinforcement of incompatible behavior. Second, the desired behavior is a replacement for the problem behavior because it leads to the same reinforcing consequence, which is gaining distance from the feared syringe. Compliance can be further enhanced by applying a well-timed positive reinforcement/distraction in the form of vigorous scratching at the withers, similar to mutual grooming among herdmates¹⁷ or a food reward for standing still with the syringe in place.

10. Avoid Punishment

Punishment stops behavior by adding something unpleasant after the behavior occurs. The use of punishment in veterinary care is not recommended.¹⁰ As a behavior-change method it is reactive rather than prophylactic and applied only after the potentially dangerous problem behavior has already occurred. Punishment can suppress warning signs of escalating anxiety but not the explosive escape or aggressive behavior. It is also subject to misuse and can adversely affect the horse-human relationship because learned fear of the individual delivering the punishment may occur. Despite the concerns, in practice fear-based behaviors are often punished with forceful, painful, and confrontational methods, including yanking on a shank or bit; waving a whip or rope; yelling sharply at the horse; and striking the horse with a hand, boot, crop, or other object.

A major shortcoming of punishment is that it does not address the fear at the root of many behavior problems, and fear cannot be reduced through force or pain. Instead, punishment validates the horse's fear and adds to the unpleasant experience. The repeated use of punishment can also lead to an ex-

Table 2. Behavior Modification Recommendations for Positive Equine Veterinary Care

1. Read equine body language and facial expressions, to recognize relaxation and respond to early signs of fear, anxiety, and sympathetic arousal.
2. Work in a location that is comfortable for the horse and remove triggers of fear, anxiety, and defensive behaviors from the environment.
3. Habituate horses to new procedures and equipment; use systematic acclimation when introducing young or inexperienced horses to a potentially fear-inducing novel object, situation, or aversive procedure.
4. When the horse has a learned fear from a previous aversive experience, use systematic desensitization to gradually and progressively reintroduce the feared, but harmless, stimulus, while the horse remains calm.
5. Apply counterconditioning to replace fear-based emotions and behavior to veterinary procedures and equipment, with relaxed emotions and behaviors.
6. Overshadowing involves stepping the horse back and forth while at the same time presenting the feared stimulus, such that the directed movement “overshadows” and prevents the fear-based defensive response.
7. Avoid the use of flooding, which triggers fear and defensive behavior, and then uses force to prevent and suppress it.
8. Shape desired behavior and strengthen it with positive reinforcement; stop negatively reinforcing the problematic escape and avoidance behaviors.
9. Avoid punishing unwanted behavior using confrontational or painful methods, which increase fear, worsen behavior problems, and negatively affect equine welfare and the horse-human relationship.
10. Use the least amount of restraint required.

pansion of fear conditioning and a worsening of the problem behavior, with greater intensity and earlier onset as the horse anticipates not only the veterinary care, but also the unpleasant punishment. Even when punishment seems to work, fear may be internalized and the behavior problem only temporarily suppressed.

11. Use the Minimum Restraint Necessary

The use of low-stress handling and minimum restraint is encouraged in positive veterinary care.^{4,6} Veterinary professionals set an example for owners and the public about how to properly handle animals in a safe and humane manner. Developing good handling skills increases the safety of caregivers, and allowing the horse to cooperate voluntarily reduces stress by giving it greater control over the situation. Physical restraint plays a crucial role in managing horse behavior and providing support, and some methods of restraint are less stressful than others. For example, a lip twitch seems to have a short-term calming effect, whereas an ear twitch operates through pain avoidance.¹⁹ When restraint is paired with discomfort or distress, simply being restrained can become a conditioned trigger for fear, anxiety, and behavior problems. This effect can be mitigated by knowing how to apply and use restraints properly, as well as where to position oneself. If the procedure is painful, chemical restraint may be advised.

12. Conclusion

The equine veterinarian plays a critical role as an agent of change by practicing positive care, educating owners and trainers, and referring to behavior professionals. Implementing positive methods in a veterinary practice takes patience and planning, but can lead to increased safety and equine welfare, as well as happier human clients. It can be accomplished by creating a relaxing environment in which

to conduct exams and procedures, recognizing and reducing fear, applying techniques such as counter-conditioning and positive reinforcement to increase desired behavior and stop problem behaviors, and using low-stress restraint properly. These and other methods described in this paper are summarized in Table 2. When positive techniques are continued between veterinary visits and over the horse's lifetime, the risk of relapse of the fear, anxiety, and behavior problems are minimized.

Acknowledgments

Dr. Foster has worked as a professor of animal learning and behavior since 1992 and conducts university-based research on equine behavior and horse-human interactions. She also consults privately on equine behavior problems and training cases as a Certified Applied Animal Behaviorist and International Association of Animal Behavior Consultants (IAABC) Certified Horse Behavior Consultant.

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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Preventing and Rehabilitating Common Healthcare Procedure Aversions

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1. Introduction

As a companion to Robin Foster's opening presentation on scientific principles of animal learning relevant to handling horses for healthcare procedures, this presentation will focus on specific application of these principles to gaining and maintaining patient compliance with veterinary care. In addition to general comments, specific recommendations will be outlined for each of five example common healthcare procedures, for routine application aimed at preventing aversions, as well as for rehabilitation of established aversions.

The 2000 *Proceedings of the American Association of Equine Practitioners* includes a detailed discussion of rehabilitation of injection shyness and other treatment aversions using scientifically sound learning principles and behavior modification techniques. The *Proceedings* paper is available on the University of Pennsylvania Havemeyer Equine Behavior Lab web page.¹

2. General Comments

Restraint and Assistance

A substantial part of the art of positive reinforcement-based behavior modification for gaining compliance with a mildly aversive procedure involves judging

and implementing the most helpful restraint for the particular animal, procedure, environment, and skill of personnel. For many horses, it is worthwhile arranging for some wiggle room and planning to safely ride out some movement. The patient's ability to move, even a little bit, as opposed to being trapped, typically reduces the risk of explosive escape or defensively aggressive responses. Care should be taken to survey the environment in anticipation of obstacles, for example a water bucket, that if contacted could cause a commotion that would add negative consequences (punishment). Particularly when rehabilitating a horse that has developed dangerous avoidance responses, personal safety gear, such as safety shoes, vest, and helmet can be helpful.

The benefit of one or more assistants will similarly vary with the procedure, the environment, and the skills of available assistants. When positive distraction and/or reward (food or scratching) is needed during the procedure, as opposed to only before and after, an assistant can be very helpful to hold the horse and deliver the distraction.

Shaping Compliance with Mildly Aversive Procedures

When *shaping* compliance with a mildly aversive procedure, attention should focus on maintaining

NOTES

the patient's relaxation and tolerance of the procedure rather than on any undesirable avoidance behavior. This enables recognition and well-timed reinforcement of relaxation with each increment of tolerance. While it helps to be prepared for any anticipated undesirable behaviors, simply ignoring undesirable responses whenever possible will speed progress. The most efficient results can be expected when assistants (as well as any observers) remain calm, relaxed, and non-reactive to any undesirable responses. Those working with the patient should maintain focus on prompting, anticipating, and immediately positively reinforcing progress. Any response that can be perceived as punishment, such as verbal or physical reprimand or punitive restraint, should be avoided.

Avoiding the "Avoidance Cycle"

It goes without saying that reactivity to aversive stimuli is a natural adaptive response. When the reaction interrupts the procedure, a common inadvertent mistake is to keep repeating the same approach. This is essentially a negative reinforcement (pressure and release) paradigm, which is particularly effective at teaching avoidance. A good rule of thumb is that if the patient successfully avoids more than once, it is best to discontinue or significantly modify the approach. Successful rehabilitation often requires a toolbox of multiple approaches to various procedures, along with a variety of positive distractors and generous rewards to offset the aversive aspect.

Primary and Secondary Positive Reinforcement/Distractor Options

For most horses, a small food tidbit is an effective primary positive reinforcement, both for routine preventative purposes or for rehabilitation of an established aversion. For extended rehabilitation sessions, a variety of treat items can be alternated to maintain interest and higher motivation than a single type. If for any reason (e.g., owner preference;

NPO restrictions) food is not an option, vigorous rhythmic scratching at the withers for most horses may be an effective substitute. For routine maintenance of compliance, a reasonable percentage of patients will quickly learn to associate the health-care provider with food treats. To prevent the food-urgent patient from becoming nudgy or nippy, food reinforcement can be delivered from a small feed pan, always reaching under the head to deliver the treat on the off side. Most horses will learn to anticipate food only when the pan is presented. When expecting a reward the horse will turn the head to the off side rather than toward the person. In some cases it may be necessary to switch from food to scratching at the withers as the primary reinforcement. An auditory secondary reinforcement, e.g., a clicker sound or a word or short phrase spoken in consistent volume and tone, if paired with the primary reinforcement, will quickly take on positive value (conditioned positive reinforcement), such that it can be effective when used alone intermittently as needed.

Caretaker "Homework"

Horse owners/caretakers can often work effectively on their own to introduce young horses comfortably to a battery of potential health care procedures, or even to perform systematic desensitization procedures for horses with established or developing aversions. As with any client education, clear instruction and follow up will ensure best results.

Acknowledgments

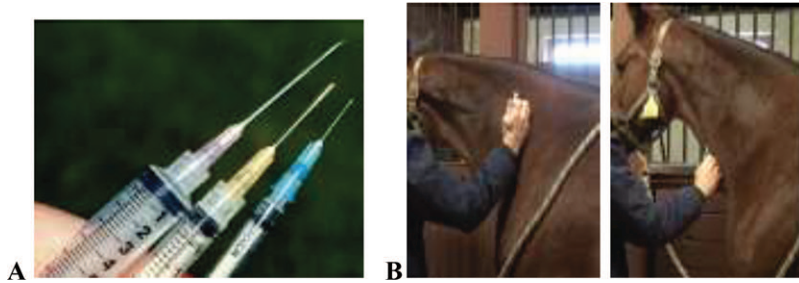
Declaration of Ethics

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Conflict of Interest

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Table 1. Needle Sticks



Routine Preventative

Equipment and Supplies

- 1) Finest needle practical: 21 gauge or 22 gauge for blood withdraw; 22 gauge to 25 gauge for low-viscosity aqueous solutions (Image A).
- 2) Small feed pan with highly palatable treats (carrot, candy, apple, alfalfa).

Behavior-Modification Principles

- 1) Select least-stressful environment available, both for animal and technician.
- 2) Consider minimal restraint necessary, allowing some safe wiggle room.
- 3) All personnel present relaxed and calm.
- 4) Make the needle stick as comfortable as possible.
 - a) Use finest needle practical.
 - b) Stabilize hand against horse, maintaining contact with any movements of the horse during the stick (Image B).
- 5) Ignore any undesirable behavior.
- 6) Offer highly palatable food treat immediately before and immediately after, always paired with verbal secondary reinforcement; e.g., the word “good” in consistent tone.
- 7) Scratch vigorously and rhythmically at the withers, simulating mutual grooming, for at least 30 seconds before and if possible continuing during skin stick (psychologically distracts, maintains positive motivational state, releases endorphins, and may compete with afferent transmission).

Established Aversion

Rehabilitation

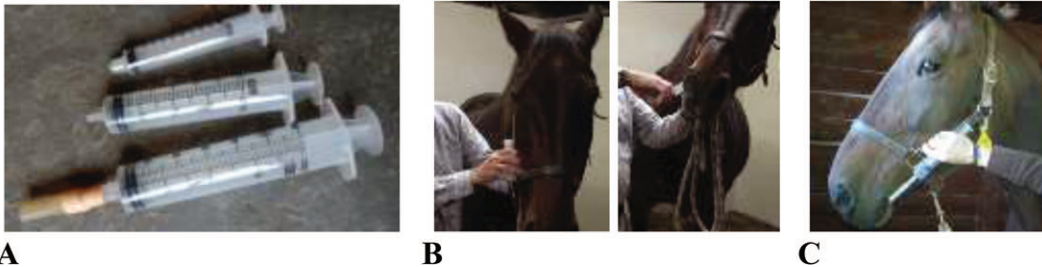
Specific Behavior-Modification Approaches to Consider, Alone or in Combination

- 1) Positive reinforcement–based systematic desensitization: pair primary and secondary reinforcement with each step in the process, first simulating injection with a skin pinch and then actual sticks of varying increasing levels of discomfort (30 g 5/8-in. to 20 g 1-in. needle). Ten sticks per increment is usually adequate.
- 2) Counter-conditioning as needed to eliminate effective avoidance behaviors: e.g., stationary-target training, teaching the horse to hold muzzle to target for several seconds or until actively released to receive food reward.

Emergency Care “Get it Done Immediately with Least Further Harm”

- 1) Overshadowing: it may be effective to perform the needle stick while leading the horse forward.
- 2) Respectfully applied skin twitch, gum-chain, or lip twitch.

Table 2. Oral Dosing



Routine Preventative

Equipment and Supplies

- 1) Smallest-diameter dose syringe practical, with mouth-friendly tip (if tip is sharp, an extension of soft tubing can be secured over the tip; Image A).
- 2) Sweet liquid (molasses, corn syrup, maple syrup, applesauce, simple syrup).
- 3) Small feed pan with highly palatable treats (carrot, candy, apple, alfalfa).

Behavior-Modification Principles

- 1) Select least-stressful environment available, both for animal and technician.
- 2) Consider minimal restraint necessary, allowing some safe wiggle room.
- 3) Select personnel who can remain relaxed and calm, safely ignoring any undesirable behavior.
- 4) Interact for a minute or so with the goal of relaxing the patient; e.g., soothing rhythmic scratching at withers, rubbing of face.
- 5) Make the dosing itself as comfortable and palatable as possible.
 - a) Use smallest dose syringe practical, with most mouth-friendly tip.
 - b) Add sweet liquid to treatment, and coat the tip of syringe with sweet liquid.
 - c) Respectful, unrushed insertion, avoiding contact of syringe tip with palate, gums, or teeth.
- 6) Suggested technique: stabilize hand and dose syringe against cheek piece of halter (Images B and C), with tip near crease of the lips, maintaining stability of the syringe and contact with the horse should it move; maintain a relaxed arm and ride out any raising or shaking of the head until the horse relaxes; then advance tip to gently contact the crease of the lips, which typically stimulates voluntary opening of the mouth, and licking of the sweetened tip; then gently rotate the syringe aiming the tip ventrally onto the tongue; calmly express liquid onto tongue, avoiding an explosive bolus.
- 7) Offer a highly palatable food treat immediately before and immediately after, always paired with verbal secondary reinforcement; e.g., the word “good” spoken in consistent tone.

Caretaker “Homework” (Discretionary)

Frequent doses of 10 cc of sweet liquid, alternating flavors following suggested routine procedure (initially daily for 10 days, then weekly or monthly) to maintain a positive interest in oral dosing.

Established Aversion

Rehabilitation

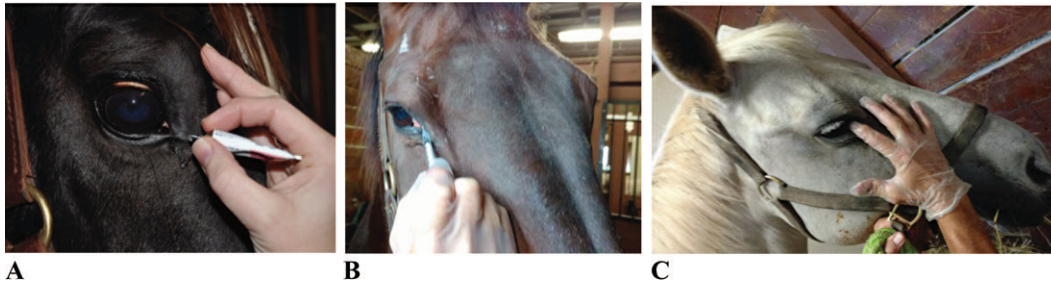
Specific Behavior-Modification Approaches to Consider, Alone or in Combination

- 1) Positive reinforcement–based systematic desensitization, first gaining tolerance of placement of the syringe along cheek piece of the halter by distracting and drawing the head low with food.
- 2) Counter-conditioning as needed to displace head lifting or shaking—stationary-target training, teaching horse to hold muzzle to target positioned at low convenient height.

Emergency Care “Get it Done Immediately with Least Further Harm”

- 1) Respectfully applied skin twitch or gum chain.

Table 3. Eye Medications



Routine Preventative

Equipment and Supplies

- 1) Eye-friendly applicator options: ophthalmic tube (Image A), soft rounded tip tuberculin syringe (Image B), or clean disposable glove (Image C).
- 2) Small feed pan with highly palatable treats (carrot, candy, apple, alfalfa).

Behavior-Modification Principles

- 1) Select least-stressful environment available, both for animal and technician.
- 2) Consider minimal restraint necessary, allowing some safe wiggle room.
- 3) Select personnel who can remain relaxed and calm, safely ignoring any undesirable behavior.
- 4) Direct application: make the application itself as comfortable as possible.
 - a) Rub face in soothing manner, rhythmically stroking approaching the medial canthus
 - b) Stabilize hand on face with relaxed arm so that hand maintains contact should the head move.
 - c) When the horse is relaxed, gently advance the applicator to the medial canthus to apply treatment.
 - d) Repeat soothing rubbing of face around eyes.

Sub-palpebral catheter:

- a) Avoid pushing air through the catheter.
- b) Express treatment slowly.
- 5) Offer highly palatable food treat immediately before and immediately after, always paired with verbal secondary reinforcement; e.g., the word “good” in consistent tone.

Caretaker “Homework” (Discretionary)

Daily routine of rubbing the face near each eye in a soothing manner, maintaining hand contact while approaching and touching the medial canthus in a respectful, soothing manner (initially with fingertip, then with a more rigid item such as tuberculin syringe or needle cap), offering a highly palatable food treat immediately before and after, as well as during as needed, paired with the verbal secondary reinforcement; e.g., “good” spoken in consistent tone just before food delivery.

Established Aversion

Rehabilitation

Specific Behavior-Modification Approaches to Consider, Alone or in Combination

- 1) Positive reinforcement–based systematic desensitization to touching of the face approaching the medial canthus. Food can be used to simultaneously draw the head to a comfortable position, distract, and then reward relaxation and increments of tolerance.
- 2) Counter-conditioning as needed to displace disruptive avoidance behaviors—stationary target training, teaching horse to hold muzzle to target positioned at low convenient height.

Emergency Care “Get it Done Immediately with Least Further Harm”

- 1) Respectfully applied skin twitch, gum-chain, or lip twitch.
- 2) Examination stocks to limit body movement.

Table 4. Intranasal Vaccination



Routine Preventative

Equipment and Supplies

- 1) Intranasal-friendly mist applicator (Image A).
- 2) Small shallow feed pan with highly palatable treat (carrot, candy, apple, alfalfa).

Behavior-Modification Principles

- 1) Select the least-stressful environment available, both for animal and technician.
- 2) Consider minimal restraint necessary, allowing some safe wiggle room.
- 3) Select personnel who can remain relaxed and calm, safely ignoring any undesirable behavior.
- 4) Make the treatment itself as comfortable as possible.
 - a) Hold the syringe in the palm with a thumb on the plunger and applicator tip extending no more than 1/4 inch beyond the little finger.
 - b) Rest hand on the face just above nostril with applicator tip pointing toward the nostril; relax that arm to move with the horse, so that the hand maintains stable contact (Image B).
 - c) When the horse is relaxed, while maintaining steady contact, rotate the hand to direct tip into the nostril simultaneously expressing the mist (Image C).
- 5) Give highly palatable food treat immediately before and immediately after, always paired with verbal secondary reinforcement; e.g., the word “good” in consistent tone.

Caretaker “Homework” (Discretionary)

Daily routine of rubbing the face near each nostril in a soothing manner, with simultaneous food treat.

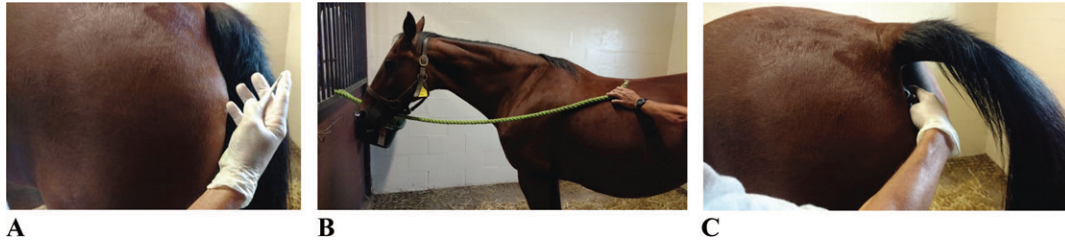
Established Aversion

Rehabilitation

Specific Behavior-Modification Approaches to Consider, Alone or in Combination

- 1) Positive reinforcement–based systematic desensitization to manipulation of the muzzle and nostril.

Table 5. Rectal Temping



Routine Preventative

Equipment and Supplies

- 1) Rectal thermometer (Image A).
- 2) Long cotton lead (10–12 ft).

Behavior-Modification Principles

- 1) Select the least-stressful environment available, both for animal and technician.
- 2) Consider simple sliding tether (Image B) to maintain directional control of the head while standing at the hip.
- 3) Remain relaxed and calm, safely ignoring any undesirable behavior.
- 4) Make the procedure itself as comfortable as possible.
 - a) Hold the thermometer in your palm with the tip along the index finger, about 1/2 inch proximal to the fingertip held in place by the thumb.
 - b) Slowly and rhythmically massage in a soothing manner just lateral to the base of the tail, gradually approaching the perineum and anus while continuing massage; this typically induces simultaneous relaxation of the anus and lifting of the tail (Image C); as that happens, give verbal secondary reinforcement.
 - c) With the index finger on the relaxed anus, advance the thermometer tip along the finger into the anus (no need to hold tail or visualize anus).
- 5) Give highly palatable food treat immediately before and immediately after, always paired with verbal secondary reinforcement; e.g., the word “good” spoken in consistent tone.

Caretaker “Homework” (Discretionary)

Daily soothing massage of the tail head, perineum, and anus as above, with food treat before and after. To teach the horse to relax the anus and lift the tail upon verbal request, add a spoken word or phrase to prompt the horse (e.g., “lift tail” or “tail up”) while massaging the tail head and perineum. After only a few pairings of the prompt with physical stimulation of the tail lifting and anus relaxing, most horses respond to just the spoken prompt and/or even your typical approach.

Established Aversion

Rehabilitation

Specific Behavior-Modification Approaches to Consider, Alone or in Combination

- 1) Positive reinforcement–based systematic desensitization massaging gradually from mid back toward the tail head; as patient relaxes at each increment, deliver primary and secondary reinforcement; as needed for distraction and/or primary reinforcement for tolerance, have assistant offer a small food pan during the massage and approach the perineum.

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Understanding Practice Expenses: Where Do 100 Pennies of Income Go?

Ann E. Dwyer, DVM

Equine veterinary practices deliver a wide range of services and products to a diverse group of patients and horse owners. Equine practices also vary in size, ranging from solo ambulatory practices to hospital practices that employ dozens of veterinarians. However, all equine veterinary businesses spend their income on a finite, consistent set of expense categories. The proportion of income that is spent on these expenses is remarkably similar in all carefully managed practices, no matter the size or shape of the business. Understanding where the money goes is an essential part of practice management that also provides the foundation for understanding the dollars that are available to be spent on veterinary compensation. Author's address: Genesee Valley Equine Clinic, LLC, 925 Chili Scottsville Road, Scottsville, NY 14546-9751; e-mail: adwyer@rochester.rr.com. © 2017 AAEP.

1. Introduction

Ordinary veterinary practice income is derived from fees for professional services. Income related to fees for veterinary services is received in the form of credit card payments, checks, and cash. This revenue is deposited in a practice bank account, and recorded in the practice bookkeeping system as well as whatever practice management system the practice uses to track of medical records and bill clients. The most common financial accounting bookkeeping system used by equine practitioners is Quickbooks.^a

It should be noted that “practice income” only occurs when revenue is actually paid to the business. Many equine practices offer extensive credit to their clients, and thus carry significant “accounts receivable”, or ledgers of monies owed for services rendered but not yet paid for. “Gross billings” do not equal “income” until currency actually changes hands.

Many veterinary practices also receive minor amounts of revenue from activity that is unrelated to veterinary practice operations. These sources include gain on sale of assets, seminar or sponsorship revenues, fees for participation in clinical trials, client billing fees, bank account interest revenue, and discounts or rebates from suppliers for volume purchases or timely payment. Accounting software programs such as Quickbooks track such revenue on the profit and loss statement separately from income related to the delivery of veterinary services. For this paper, only income related to the actual provision of veterinary services will be discussed.

Practice Expense

Practice management analytics are simplified if the practice bookkeeping system is set up so that all routine business expenses are coded and tracked consistently. A comprehensive Equine Veterinary Practice Chart of Accounts (EVPCOA) is available as an inexpensive publication.¹ This publication

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presents guidelines for the organization of the practice bookkeeping system that segregates every penny of practice expense into simple, logical categories enumerated by specific numeric codes that reflect the operation of equine practices of all sizes. Practice expenses related to the delivery of veterinary services in equine practice can be grouped in 5 categories as outlined in the EVPCOA:

1. Cost of professional services (COPS; or cost of goods sold [COGS])
2. Facility expense
3. Office expense
4. Labor expense
5. Depreciation expense

Integrating the categories listed in the EVPCOA with the practice's Quickbooks system provides a powerful tool for practice financial analytics. As long as income and expenses are entered in a timely and consistent fashion, the Quickbooks accounting software program provides reports that analyze the percentage of income that is spent on these 5 categories with the click of a mouse for any given year, quarter, month, or other interval, and readily compares the results to the preceding interval.

COPS, also known as COGS, is one of the largest expense categories of any equine practice. It captures the practice costs that are directly related to the delivery of veterinary services. In the delivery of their services, equine practitioners routinely do examinations, treatments, and surgeries. They also perform a variety of imaging procedures, and administer and dispense many pharmaceuticals. They order laboratory tests in house and send samples to outside laboratories. Delivery of care involves the consumption of a variety of supplies including bandages, catheters, suture, gloves, syringes, needles, etc. Hospital practices incur costs to purchase feed and bedding. All these expenses fall into the category of COPS/COGS, which can be thought of as the direct costs relating to the "hands-on" delivery of patient care. Examples of expenses that qualify as COPS/COGS include bills paid to pharmaceutical distributors, bills paid to reference laboratories, the cost of vaccines and the expenses related to archival and retrieval of digital images.

Facility expense, as defined by the EVPCOA is the cost involved in upkeep of the various elements of the practice that allow equine veterinarians to deliver their services. These elements include the day-to-day expenses, rent, taxes, and repair costs of any "brick-and-mortar" structures associated with the business, the expenses involved in operating and maintaining ambulatory vehicles, the telephone and Internet costs associated with the business, and the costs to insure the variety of elements mentioned. Examples of facility expenses include utility bills, vehicle fuel and repair bills, cell phone bills, business insurance bills, and property taxes.

Office expense details the direct costs involved in running the business part of the practice. These costs can be thought of as the expenses that are incurred that are *separate* from the direct delivery of patient care; costs that any business would require just to "operate" as a business that charges fees for services. Office expense details the costs of providing access to veterinary service, and collecting money. It includes costs to advertise and promote the business, and expenses charged by bank accounts, credit card processors, and collection agencies. It also includes the cost of purchasing computer and general office supplies, postage and printing costs and the fees paid to payroll companies, accountants, and legal advisors.

Labor expense includes all the costs of employing and supporting the employees of the practice. Wages make up the largest portion of this part of this practice expense, and include both the wages paid to veterinarians and the wages paid to various support staff. Payroll taxes, including FICA, Medicare, state and federal unemployment insurance, and other mandatory state insurance programs related to payroll make up an often overlooked but significant portion of labor costs. Other expenses relating to practice labor costs include the costs of workers compensation insurance, professional liability insurance, and expense related to employee continuing education. Finally, premiums paid by the employer for employee health insurance programs, and contributions made to employer sponsored retirement plans round out the large amount of money that all practices spend on labor expense to compensate their veterinary and support staff.

Depreciation expense is a system that is used for accounting and tax purposes to spread out the cost of equipment and other fixed assets over time. It requires a little accounting knowledge to understand. Unlike the other categories that involve paying a bill from a bank account, depreciation expense is a method of cost allocation, and the expense entries for depreciation require accountant oversight as well as management decisions related to prevailing tax laws and codes.

Depreciation expense relates to the purchase of items known as "fixed assets," large purchases that will be used in the business for more than 1 year. Accountants vary in their guidelines for what equipment/items constitute a depreciable asset versus small items that can be written off the year they are purchased, but in general, any item that costs more than a few hundred dollars that is expected to last more than a year is considered for the depreciation schedule. Fixed-asset categories of depreciable items commonly used in equine practice include professional equipment (ultrasound machines, digital radiology equipment, laboratory equipment, etc.), computer hardware and software, office equipment, furniture and fixtures, facility maintenance equipment, and practice vehicles. Large practices may also have livestock (e.g., embryo transfer mares),

and buildings. Some may have leasehold or land improvements as depreciable fixed assets.

The concept of “straight-line” (SL) depreciation relates to Internal Revenue Service (IRS) rules that assign an annual portion of the original cost of the item as an expense that approximates the ordinary wear or life span of that item. The concept can be understood by thinking about what happens when a set of truck tires is purchased. Assume for this example that this set of 4 tires cost \$1000 and are expected to last 50,000 miles. The tires are mounted on a truck that travels an average of 10,000 miles per year. If the tire tread is inspected each year, it will be apparent that 20% of the tread has worn away, thus the useful life of each tire has reduced by 20%. Simple math predicts that the tires will need to be replaced in 5 years. If the tires were a depreciable business asset, they would be listed as a “5-year asset.” Even though the tires cost \$1000 up front, the practice would not be allowed to deduct the full amount paid for the tires in the year they were purchased. Instead, the accounting system would make an entry of a \$200 expense every year for 5 years to reduce taxable income by the amount of estimated wear and tear on the asset. The costs of purchase would be “recovered” over the estimated life of the item.

The Internal Revenue Service has rules that dictate the economic life of various types of fixed assets for tax and accounting purposes. Most veterinary equipment purchases, computers and vehicles are classed as “5-year assets” by the IRS (meaning that the costs are recovered over a span of 5 years), whereas office furniture and fixtures are classed as “7-year assets” (costs are recovered over a span of 7 years). There are other forms of accelerated depreciation that are involved in practice financial management, including so called “bonus depreciation” as outlined by Section 179 of the IRS tax code that are beyond the scope of this presentation, but the concept of SL depreciation is one that every practitioner should understand.

Bookkeeping for depreciation expense is overseen by the practice accountant, but decisions on fixed-asset purchases as they relate to the percentage of practice income that a practice can afford to invest over time to keep up with technology, replace broken or outdated equipment, and offer advanced services are the responsibility of the practice owner(s). In this lecture, the economics of arriving at a reasonable budget for investment in fixed assets over time will be discussed; this budget results in a relatively fixed and predictable amount of depreciation expense annually.

Where Does Practice Income Go?

All equine practices must take in at least several hundred thousand dollars of income in order to deliver patient services and compensate the owners and employees. The largest practices take in several million dollars of income. These numbers are intimidating for the associate practitioner whose

primary concern is clinical management of cases, and for relatively young veterinarians contemplating practice ownership or compensation negotiations. But just as the concept of depreciation can be simplified by thinking about the tangible example of tread wear on a tire, the “many zeroes” of practice finance can be simplified by scaling the big numbers down to an easily imagined level.

Practices that take in hundreds of thousands to millions of dollars do it essentially one dollar at a time. Each dollar of income can be thought of as 100 pennies. Attendees for this talk will confer in small groups to arrive at an educated guess of “how many pennies” of an imaginary dollar of income are spent on each of the categories listed above. The following worksheet can be used for attendees to record their discussion group’s best guess as to the allocation of how each 100 pennies of practice income is spent. After the groups present their “best guess” of expense allocations, the actual allocations from private practice data will be presented.

Category	Your Best Guess (# Pennies out of 100)	Real Practice Data (# Pennies out of 100)
Cost of professional services		
Facility expense		
Office expense		
Depreciation expense		
Labor expense		
Are any of the 100 pennies spent on something else?		

This lecture will use real data from a mid-sized practice to detail practice expenses from a typical year and demonstrate how these predictable expenses relate to practice profit and veterinary compensation. The data that will be displayed is drawn from one practice, but is consistent with metrics published or observed by professional analysts who have tracked expense statistics and net income from a broad spectrum of equine practices.^{b,c}

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.

Reference and Footnotes

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^aQuickbooks, Intuit, Inc., Mountain View, CA 94043.

^bHeinke, ML, Grafton, OH (personal communication, 2004–2016).

^cChalk, JA, Southlake, TX (Notes taken during lecture session on “Succession Planning as a Business Strategy”, AAEP 62nd Annual meeting, Orlando, FL, Dec 5, 2016).

Understanding Veterinary Compensation: Strategies to Track the Pennies Earned

Ann E. Dwyer, DVM

Equine practice economics dictate that approximately 25¢ out of every dollar of revenue that a practitioner generates are available to be spent on veterinary compensation. Veterinary compensation costs include many elements beyond the W-2 wages in a paycheck, including expense associated with practice-sponsored benefits and the costs of payroll taxes and payroll-associated insurance programs. The wage portion of veterinary compensation is often incentivized by bonus offerings that are linked to revenue generated by the employee; these compensation agreements are called “base plus” wage plans. Practice owners and associates will benefit from studying the details of practice economics as they relate to compensation agreements. Knowledge of the laws and limitations that apply to a given employment situation will help both sides agree on fair and affordable compensation plans. Author’s address: Genesee Valley Equine Clinic, LLC, 925 Chili Scottsville Road, Scottsville, NY 14546-9751; e-mail: adwyer@rochester.rr.com. © 2017 AAEP.

1. Introduction

Veterinary Compensation Essentials

The word “compensate” is derived from the Latin word, “compensationem,” which means a weighting of one thing against another, a balancing. In simple terms, veterinarians employed by equine practices spend their professional time providing veterinary goods and services to patients. The animal owner(s) pay the practice money in exchange for those goods and services; this money is practice income. As was explained in the previous talk, practice income is spent in many different areas, including the cost of drugs and supplies, the costs of support staff labor, and the costs involved in operating an office, providing ambulatory or hospital services, and the cost of purchasing equipment and assets. The mathematics of practice economics show that for every dollar of revenue that an equine

practice takes in, a finite amount of money, approximately 23¢ to 26¢ (or 23% to 26% of practice revenue) is available for veterinary compensation. The money that is available for compensation is spent not only on veterinary wages but also on a variety of benefits and perquisites. The costs of compensation also include the payroll-related taxes and insurance payments that the practice must pay to federal and state government agencies.

Most equine veterinarians are not trained in economics or business during their education, thus are easily overwhelmed when thinking about the dollars involved in managing a practice, given that the numbers quickly amount to hundreds of thousands, if not millions, of dollars. But any veterinarian can understand the tangible reality of a stack of 100 pennies that adds up to a single dollar. This talk will frame the elements of affordable and fair veterinary compensation by explaining how each dollar that

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Table 1. Sample Practice Annual Expense for Benefits Provided to an Employed Veterinarians

Benefit or Perquisite	Sample Practice Expense per Veterinarian (Varies with Individual Practice, and Employee Circumstances)
Health insurance premium	\$3000
Retirement plan contribution	\$2000
Continuing education registration/travel	\$1800
Professional dues	\$800
Professional licenses	\$600
Cell phone and Internet access	\$600
Personal use of practice vehicle (commuting and errands) while on call	\$600
Veterinary service discounts for personal animals	\$600
Total	\$10,000

a practice spends on compensation actually breaks down into pennies that are spent on W-2 wages, employee benefits, payroll taxes, and employment-related government insurance programs. Armed with this perspective, a system for tracking individual production income and relating it to a variable compensation program will be outlined.

Compensation Has Many Elements

Wages, or “W-2 income” as reported to the Internal Revenue Service, are the largest portion of veterinary compensation expense. Wages are paid to employees in the form of regular paychecks that are issued on a weekly or biweekly basis. Additional W-2 income is paid out by some practices as bonus paychecks that are linked to employee production or performance, emergency service compensation, or issued as discretionary compensation by the practice owners. Bonus compensation may be issued on a monthly, quarterly, or annual basis, depending on individual contractual agreements.

Practices vary in the benefits and perquisites offered in their compensation packages, but common nonwage benefits include employer-paid portions of health insurance premiums, employer contributions to retirement accounts, and employer paid “time off”—paid days that are used for vacation, holidays, or family or medical leave. Most practices offer some compensation for the employee’s professional continuing education costs and an allowance for professional association dues and veterinary license expense. Equine practices that offer ambulatory services may allow and pay for limited personal use of a practice vehicle and may either provide a cell phone or subsidize a portion of the costs of phone and Internet usage. Many practices offer a discount on veterinary goods and services that are purchased for personally owned animals, or subsidize a portion of the costs of veterinary medical insurance policies.

The largest sums that practices spend on employee benefits go toward health insurance premiums, contributions to retirement plans, and paying for the costs of continuing education, but the costs of other perquisites such as association dues and dis-

counts on veterinary services are not inconsequential. An example of representative total dollar costs of common annual benefits and perquisites from a sample practice is listed in Table 1. The sums listed are discretionary so they vary from one practice to the next, but the numbers in the table are reflective of the costs of benefits commonly reported in budgets of prominent equine practices.

For every dollar that is paid to a veterinarian as direct W-2 wages, the additional costs that a practice spends on such benefits and perquisites can easily exceed 15¢. Getting back to the “big numbers” involved in practice finance, this means that for every \$100,000 of practice income that a practice spends on W-2 wages of employed associate veterinarians, an additional \$15,000 is commonly spent on benefit programs for those team members. In addition, a portion of the W-2 wages that are paid out reflect “paid time off” (PTO): days that are used for vacation or sick leave. Employees should realize that such PTO is an additional benefit that the practice provides, and that the cost of such PTO must be factored into any discussion of compensation.

Payroll tax costs and the expense of mandatory insurance programs that are based on W-2 wages comprise another significant element of the costs of compensation. Depending on the state of employment, these costs may exceed 11¢ for every dollar spent on W-2 wages. Table 2 outlines the current (2017) costs of payroll taxes that go to support the Federal FICA (Social Security) and Medicare programs as well as employer costs levied by New York State (where the author’s practice is located) for various mandatory programs. The mandatory programs will vary by state. The payroll taxes and insurance costs listed in this table are automatically deducted from the practice bank account with each payroll cycle.

For every dollar that is spent on W-2 wages, note that more than an additional 11¢ are spent on these programs. This means that for every \$100,000 dollars that are paid to employees as wages, approximately \$11,500 of additional practice money is spent on mandatory Federal and State payroll taxes and

Table 2. Sample Costs of Government Payroll Taxes and Mandatory Payroll Related Insurance Programs per \$1.00 of W-2 Wages Paid to an Associate

Payroll Tax or Insurance Program	Pennies Owed per \$1 of Veterinary W-2 Wage Paid Out	Does Cost Vary by State or Insurance Claim History?
FICA (Social Security)	6.20¢	No, federal mandate
Medicare	1.45¢	No, federal mandate
Federal unemployment insurance	0.60¢	Yes
State unemployment insurance	1.11¢	Yes
Workers' compensation insurance	2.12¢	Yes
TOTAL	11.48¢	Yes

payroll related insurance programs. These are true “costs of compensation” as these programs were created for the benefit of the employees over their life span. The programs are in place to act as financial repositories that will provide compensation to the employee from the government in the event of retirement, unemployment, medical needs in old age, disability, or workplace injury.

Employee Payroll Taxes, Income Taxes, and Elected Pre-Tax Payroll Deductions

Payroll taxes are levied on individual employees as well as employers. In fact, employees pay exactly the same number of pennies to the government for FICA (Social Security) and Medicare that employers do! This money is withheld automatically from the employee’s paycheck and is deposited to the respective government account. Thus out of every \$1.00 of W-2 wage that is paid from the practice to the employee, the government withholds 6.20¢ for social security and 1.45¢ for Medicare from the employee, so each “dollar of pay” is thus reduced to a 92.45¢ cash before any other withholdings. Employees also may see entries for minor withholdings from their paycheck for other state mandated programs for disability or unemployment. Beginning in 2018, many employees may see additional deductions subtracted due to recently implemented laws relating to the expansion of “Family and Medical Leave” compensation programs.

In addition to payroll taxes, all employees must pay annual federal income taxes and many states (including the author’s state of New York) assess income taxes as well. Employees who receive W-2 wages have an amount that approximates the predicted taxes that will be owed on each dollar of

payroll deducted from the gross pay issued at every paycheck as income tax “withholdings.” This amount is paid to the respective government entities and then the total is reconciled every year when the individual files their tax return; in some cases additional money is owed to the government and other cases the government owes the individual a refund. The amount that is withheld from the paycheck is based on marital status, the number of dependents that will be claimed by the employee on their tax return, as well as the applicable tax bracket that is anticipated for the annual wages of the employee. Individual circumstances and the state of residence will dictate the amount of income tax that is withheld from an employee’s paycheck, but the amount often exceeds 15% to 20%, or 15¢ to 20¢ of every dollar.

In today’s financial world the cost of the two largest workplace benefits are rarely borne entirely by the employer. A portion of the employee health insurance premiums are commonly paid by the employee, and employer retirement plan contributions for plans such as 401Ks or SIMPLE IRA accounts are usually matched to voluntary contributions elected by the employee. In addition, many employees may choose to allocate a portion of their paycheck to allocate some income to tax advantaged programs such as health savings accounts. Most of these voluntary employee costs can be paid for with “pre-tax dollars.” This means that the payroll taxes that were outlined above are taken out of the income that is “left over” after deductions have been made for the elected benefit program(s). An example of how “pre-tax” dollars might be earmarked for benefit programs from a dollar of a typical paycheck is outlined in Table 3. The second column of the

Table 3. Comparison of the Amount of a “W-2 Wage Dollar” Subject to FICA and Medicare Payroll Tax if Pre-Tax Benefit Programs Are Elected or Not

	Employee Who Elects Pre-Tax Deductions	Employee Who Declines Pre-Tax Deductions
Original W-2 wage amount	100¢	100¢
Employee contribution to retirement account (5%)	(5¢)	0
Employee share of health insurance premium	(3¢)	0
Employee contribution to health savings account	(2¢)	0
Amount of W-2 wage subject to payroll taxes	90¢	100¢

table compares the resultant payroll tax basis of an employee who elects typical pre-tax deductions with that of an employee with no elected deductions (third column).

The combined FICA and Medicare taxes on 90¢ of payroll for the employee who opts for pre-tax deductions are \$0.068; the taxes on \$1.00 of payroll for the employee who does not opt for deductions are \$0.077. Electing to pay the employee portion of the benefits cited in the previous example would result in payroll tax savings of \$90 for every \$10,000 of gross pay, or a savings of approximately \$675 in FICA and Medicare payroll taxes on an annual W-2 income of \$75,000. The total effect on FICA and Medicare taxes in this example is a savings of approximately 10%; the effect that similar deductions would have on other income taxes varies with individual circumstances and state.

The Reality of a Paycheck: Key Numbers to Understand
The mandatory costs that both employer and employee pay for payroll taxes have been explained in the previous section, and the advantages realized when employees elect to pay their portion of certain employment programs through deductions of pre-tax payroll dollars have been outlined above. The costs that all employers pay to provide common benefits and perquisites have also been described. These “bare facts” of compensation mean that no matter whether \$1, or \$100, or \$10,000 are spent by the practice on associate W-2 payroll wages, the original amount does NOT translate to equal additions to the employee wallet, or equal subtractions from the practice bank account! There are a number of “hidden costs” of compensation as described previously. Both employees (veterinary associates) and employers (practice owners) must understand the “reality of a paycheck,” which can be summarized as follows:

For every dollar of W-2 wage that is paid to an associate out of practice income revenues:

1. The *employee* (associate veterinarian) takes home 25% to 30% LESS cash, depending on income taxes, employee payroll taxes, and pre-tax W-2 compensation that the employee earmarks to spend on benefits such as retirement savings, health insurance, or a health savings account.
2. The *employer* (practice) spends 25% to 30% MORE cash, depending on the amount paid out for employer payroll taxes, government-mandated insurance programs linked to payroll, and the costs of practice-benefit programs and perquisites.

Employers and employees who keep these “simple financial facts of life” in mind during compensation discussions will be at an advantage when negotiating a compensation agreement that is affordable to the practice and fair for both parties.

The other “essential fact” that all parties must understand is that equine practices can afford to spend approximately 25% of practice income on the total costs of compensation paid out for veterinary work. The exact number may vary a few percentage points up or down given the scope or size of the practice, but this “25% rule” is a useful “stake in the ground” that should be kept in mind when budgeting for practice labor expense or entering compensation negotiations. That figure represents the full cost of compensation, including wages, benefits, perquisites, payroll taxes, and employment-related insurance costs.

W-2 Wage Compensation for Veterinary Associates—How Are Wages Paid?

Recent survey data^a polling veterinarians from all arms of the veterinary profession suggests that approximately 25% of veterinarians are paid a straight annual salary, another 27% are paid strictly on production, and the remaining 48% are paid through a hybrid method that combines a guaranteed base salary with a production incentive. The latter compensation scheme is often termed a “base plus” plan.

Veterinarians who are paid W-2 wages through a straight salary arrangement know that their wages for a given fiscal year of employment will be a set amount. The compensation terms are often spelled out in a contract agreement. A certain salary amount is agreed to be paid out for a certain time interval, usually a year, but sometimes broken down into a weekly or monthly sum. W-2 wage compensation for any subsequent year that follows is negotiated between the employer and the employee. The employer may base decisions on changes in compensation on the length of tenure the employee has with the practice, on practice profitability, on the individual income that is produced by the employee, on team or individual performance metrics or by some combination of these analytics. The employee may negotiate for changes in the base salary in sequential years by citing measurable performance metrics that have been met or by some other criteria.

Veterinarians who are paid W-2 wages that are based solely on income production receive variable pay, depending on the amount of income that is collected in a specified period. The practice management and accounting software tracks the income that the individual bills for and collects, and the veterinarian’s paycheck is adjusted at regular intervals, based on the income that is generated. In many practices the pre-agreed W-2 wage amount that is linked to collected veterinary service income is different than the W-2 wage amount that is linked to the sale of veterinary products. The amount of monetary compensation linked to veterinary services is higher than that linked to product sales, because recent changes in the delivery and cost of drugs and certain supplies has reduced the profitability of product sales. In large practices, the pro-

duction income that is paid to hospital clinicians and/or specialists may be based on a scale that is different than that used for ambulatory clinicians.

Veterinarians who are paid on a hybrid “base plus” compensation agreement are guaranteed a base W-2 wage that is specified as an annual, weekly, or monthly salary. This base amount is paid out no matter what level of income production is generated by the employee. However, the compensation agreement promises the employee additional compensation if a certain performance threshold is exceeded. The most common performance threshold is a specified amount of collected income within a set time period. That period may be tracked monthly, quarterly, or annually. Veterinarians who enter into employment agreements with relatively low base salaries may be eligible for bonus checks on a monthly or quarterly basis. Veterinarians who have agreements with relatively high base salaries may only be eligible for an annual bonus check. In either case, if the individual generates income for the practice that exceeds the specified threshold, the employee can realize significant increases in take home pay. Veterinarians who qualify for bonus payments usually reach their threshold income goals through a combination of well-honed clinical skills, increased efficiency, and fine-tuned skills in client relations that promote repeat business and loyalty.

The main advantage of a straight salary compensation method is that it provides a fixed income that is guaranteed. This method is often used for new hires or young associates who are still cultivating their clinical skill set and efficiency. Disadvantages to the employee include the risk of being underpaid for the contribution that is being made to the practice. The employer, on the other hand, risks overpaying a poorly producing employee by guaranteeing a salary that may exceed the employee contribution to the practice financial picture.

Advantages of wages that are strictly based on production are that “pay” is linked to actual practice income, which can be enhanced through effort on the employee’s part, including enhanced clinical skills, increased efficiency, and the cultivation of client loyalty. Thus, the employee has a lot of control over the outcome, but as compensation expense is directly linked to actual revenue, the system protects the employer from paying too much. There is no “ceiling” for the total sum that can be earned by the employee beyond the volume of services that the practitioner can realistically provide and the fees that the practice charges for those services. However, living on pay based solely on production can be challenging due to the seasonal nature of equine practice, which always includes a “slow time” where income lags and the resultant W-2 income for the associate would be low.

Various hybrid “base plus” compensation methods have become common in equine practice because they provide the comfort and steady cash flow of a

guaranteed weekly or biweekly paycheck, yet also offer the incentive of extra pay for high-performing employees. Although any production-based compensation method can foster unhealthy competition where team members volley for clients, cases, and income, practices that craft thoughtful “base plus” compensation schedules can create agreements that reward individual excellence and efficiency without undermining collegial teamwork and cooperation.

Clarifying Compensation Expectations

Whatever compensation method is agreed on between employer and employee, the specifics should be spelled out in writing. The various elements including wages, benefits, and perquisites that the practice offers are outlined for a given employment period, usually 1 year. Whether in the form of a contract or an employment offer, documentation of compensation terms should be clear and specific. Prior to renewal of any employment agreement, both employer and employee should sit down and discuss compensation so that both are “on the same page” as to how and when the various costs of compensation will be paid out. The employee should be updated about opportunities available for participation in various pre-tax payroll deduction programs. Both employer and employee should be clear on issues such as license and dues renewal, and cell phone usage, and the details of options for retirement and health plan contributions, and discounts on services for personal animals must be discussed. Registration and travel costs for continuing education, as well as time off for vacation, medical or family leave should be clearly understood. In a nutshell, the practice should “say what it is going to do, and do what it says!”

The employee should have a clear picture of what money and benefits the practice has promised and should not be surprised by any allotments of time, resources, or money as the year unfolds and the various elements of compensation are paid out. The employee should also have a good grasp of the expectations that the practice has for their contribution to the business. Associates and practice owners both benefit from well-designed, regular reports that share data on the costs of compensation as well as individual production figures that track how well W-2 wages and benefit costs are linked to the economic value that the employee provides to the practice.

Using Practice Financial Data to Track Production

During more than 2 decades of practice ownership, the author has drafted a variety of “base plus” compensation agreements that provide guaranteed base and incentivized bonus W-2 wages as well as a variety of benefits to the veterinarians that have worked within the practice. The lecture will show a method that this practice has used to give feedback to employees on the cost of their compensation. This method tracks income production on an indi-

vidual basis monthly, quarterly, and annually and details the cost of W-2 wages, various benefits and perquisites on a similar basis. It provides a running “meter” for both employer and employee to track progress toward set goals of collected income production. The metrics used take the seasonal nature of equine practice into account, yet still provide a barometer to predict whether a set goal is likely to be met or not.

One final comment on setting production thresholds for “base plus” compensation strategies: a variety of approaches can work, but it is important for both employer and employee to be careful in calculating the costs/outcomes of various “what-if” scenarios. *The key fact to keep in mind is that a practice can afford to spend approximately 25% of the income an individual generates on direct veterinary compensation costs.* Some practices may opt

to pay a bit more, some a bit less, depending on desired profit and other factors, but no practice can afford to pay costs of compensation that total a *lot more* than 25% of income generated.

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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.

Footnote

^a2013 survey data reported on the Web site, www.veterinarybusinessadvisors.com.

Navigating the Path to Successful Partnerships

Ky Mortensen, JD, MBA

This presentation explores the value and the challenges of veterinary partnerships and provides insight on how to be a great partner in business, how to get the most from your existing partnerships, and what to look for in the selection of new partners. Author's address: 193 Coy Road, Weatherford, TX 76087; e-mail: ky.mortensen@inovapartners.com. © 2017 AAEP.

1. Introduction

In the business of veterinary medicine, partnership with other veterinarians can create opportunity for growth in many ways. The synergies, access to capital, and economies of scale created by an expansion through partnership can make it a desirable option for growing your practice. Several forms of partnership exist, not only the traditional partnering of two or more veterinarians, but also partnerships in a broader sense including potential mergers of two or more practices and corporate partnership opportunities. When evaluating a potential partnership, or examining an existing partnership, of priority is the need for a methodical examination as to why the partnership is necessary, what benefits it presents, what risks it could entail, and whether the expectations of the partnership have been thoroughly communicated to all stakeholders. In any business, the alignment of values, a carefully selected leadership structure, and a solid legal foundation will be of value in setting the stage for a prosperous environment. This presentation will focus on these three elements of successful business management as it applies to today's landscape of veterinary partnership opportunities.

2. Strategic Alignment

Mergers and partnerships in business have been happening since the beginning of trade. Here in the Americas, European trappers strategically aligned themselves with various Indian tribes during the 17th-century fur trade in an effort to lay claim to trapping grounds, protect waterways, and ultimately avail themselves of the potential to receive greater return for their efforts. And why not? We all want the maximum benefit from our time and labor. If partnering can create an advantage, or ensure a smoother road, it is natural to explore the possibilities.

In the healthcare industries we have seen a significant change in the mid-to-late 1900s from the one-doctor practices making house calls, to doctor-owned hospitals, to the onslaught of partnership ventures including investor-owned healthcare organizations.

As similar concepts took root in the veterinary industry, we have seen the growth of organizations such as VCA and Banfield create significant corporate footprints in the marketplace. This year brought about the acquisition of VCA by Mars Corporation (owners of Banfield), collectively representing nearly 16% of the companion-animal market and employing approximately 12.6% of the veterinary job force.¹ In the equine veterinary marketplace we are beginning to see the shift as well. Joint

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ventures and corporate partnerships are being explored with more interest than ever before.

Regardless of the type of expansion you seek through a potential partnership, the key elements of examining any such venture are the same. Does this make sense financially and can I prosper in this new environment? Do we share the same values? Does the leadership structure make sense? And how best to establish our legal framework to protect everyone's interest in the long term?

3. Understanding What Partnership Means

Partnerships are explored for one reason: an increase in return. Be it more time or more money, we want something more and the option of a partnership holds that promise of return. With risk can come reward. And partnering always carries some degree of risk. Why? Because you are giving something up in the hopes of gain and the outcome is unknown. The laws of nature demand that when you choose to do one thing, you are in effect choosing not to do something else. So for all of the gain that partnership represents, what is it that could be lost? Two things: money and control. Two things near and dear to the heart of every current or future business owner.

Regardless of how the partnership is structured, you will now be making decisions with someone else involved. Even in a 50/50 partnership deal, there will be an alpha. If you have been the sole owner, or majority owner of a practice and are bringing on a partner or looking at a partnership opportunity, your level of control will now be shared in some way. Can you accept that? Do you know what it means? How can you prepare for this inevitable change, and even more importantly, make it work to your advantage?

4. Maintaining Your Heading

Your career up to this point has likely been in alignment with deeply held personal values. Consider what you value above all the rest and how those values are manifest in your business? Do you value profitability? Do you value culture? Is it having a name in the industry? Position in the marketplace? When you consider Maslow's hierarchy of human needs, you'll find that there is a similar pyramid in business. First there is the basic need of the business to support itself, to generate enough cash flow to stay afloat. Next, the business needs to achieve some measure of profitability along some meaningful timeline in order to sustain itself long term. But after that, it gets interesting. Most businesses that have been in business over 5 years have demonstrated an ability to generate cash flow and to produce a profit. But the differences become staggering after that simple test. Are they fun places to be? Is there much turnover? Do the employees feel valued? Empowered? Are there systems in place to ensure longevity? And what of the long-term vision for the owners? What exit strategies

are they exploring? Are we in business to make money, or are we trying to right some fundamental wrong in the world? Is there a culture, and what is it, and why? You can get a cup of coffee at Starbucks or the Waffle House, but that is the likely the only similarity in these two enterprises. Why? Culture and values. What are yours?

In the business world you'll hear a lot about increasing profitability. Financial advisors will often talk about EBIDA (earnings before interest depreciation and amortization), which is simply a truer measurement of profit before deducting the above. It is an exercise to determine how much is left over during a specifically selected time period. It is important because that gap is an indication of how that business is judged by the world. But how much are they putting back into the company to develop the kind of culture that they want. How much is being spent on enriching the workplace so that everybody loves coming to work in that environment? How much is spent on recruitment, staff development, team building, internal customer service, and giving back? I have seen businesses that could easily be at 20% profit margins, and by choice they are operating at around 9% simply because they have made it a priority to put money back into building a culture where they can thrive. Why? They value something else. They may still have their eye on business value, long-term ability to sell their shares, and retire, but they see the path between here and there differently. And it's not necessarily all about a number. It's about a feeling. About an atmosphere of abundance and wellbeing, it might be about peace and fulfillment and the individual perception of what brings peace and fulfillment to fruition. And let's not forget ... 9% of a billion is a whole lot more than 20% of a million.

Partners need to be on the same page in that regard. These expectations of cash flow, of profitability, expected key performance indicators (KPIs), and of corporate culture are crucial discussions that need to take place at the outset of the partnership. Without these areas being thoroughly explored and defined, the alignment is likely doomed from the beginning. The definition of each partner's success needs to at minimum be communicated to the others so that the rest of the partners are on notice of what each partner requires in order to be fulfilled as a professional and ultimately to consider the partnership a successful venture.

5. Selecting the Captain and Crew

Partnership discussions usually begin with the thrust being financial gain. This is an obvious driver and it makes sense that greater wealth be the result. As the numbers are evaluated and the potential synergies explored, the "doing of it" will ultimately take over as a crucial factor. Similar to a marriage, the dating period can be intoxicating, the wedding a massive celebration, and the honeymoon complete bliss. But then the work starts. Someone needs to

sweep the floor, take out the trash, manage the finances, and so forth. It is no different in the merging of practices or the growth of a partnership. Someone has to be in charge. Too often this discussion of authority is treated lightly with a sense of entitlement based on years in the profession, who has more seniority, whose practice is worth more, or who does a better job of selling themselves as the obvious choice during the negotiation phase.

Leadership

The skills required for getting a job and the skills required for actually doing a job are not usually the same thing. In 1969 a satirical little book was published by Laurence J. Peter that the world would come to know as the Peter principle. It is a concept stating that the selection of a candidate for a position is often based on the candidate's performance in their current role, rather than on abilities relevant to the intended role.² In other words, the fact that an owner of a practice seems to have been successful based on a set of financials is not necessarily an indicator that they will be successful steering the ship when the organization changes culture, doubles in size, introduces a new set of players, requires more systems, etc. This is important as new associates join the partnership realm or when practices join forces. Determinations need to be made as to who will have managing roles, who will simply be equity owners, and how that leadership structure is to function. Confusion or surprises after the paperwork is done will lead to mistrust, disappointment, and turf wars that can result in a failed effort.

In addition, owners of practices are typically the original founders of that practice and as such can be prime candidates for founder's syndrome, or founderitis. This is a popular term for a difficulty faced by organizations where one or more founders maintain disproportionate power and influence following the effective initial establishment of the project, leading to a wide range of problems for both the organization and those involved in it.³ The passion and charisma of the founder or founders, which was such an important reason for the successful establishment of the organization, becomes a limiting and destructive force rather than the creative and productive one it was in the early stages.³ Leaders suffering from this malady often view themselves as indispensable to the organization, they feel entitled, and do not trust anyone to do the job quite as well as they would have done it.

This presents a significant challenge for practice owners joining forces. Personalities, egos, and lack of an in-depth look at the governance structure and leadership chain of command can create serious issues for joint ventures. Be cognizant of this likely obstacle and be prepared to address it early in the game to avoid the conflicts it represents, and the eventual loss of trust it can create.

Systems

Most veterinarians are technical people, they understand technical viewpoints and technical approaches to solving problems. Technical people are very adept at running a clinic. They may not be as adept at running a business. They are likely very ill equipped to run an enterprise.⁴

As described in Peter Gerber's book, *The E-Myth*, the most vital component of establishing a successful enterprise is the implementation of successful systems and the art of managing those systems rather than managing people. Veterinary medicine lends itself well to being run according to systems, to given protocol, and a set of standard operating procedures. When the systems are in place, it is simply a matter of monitoring the success of each system, measuring for improvement, and adjusting as necessary over time. Without systems, the ship is inclined to get seriously off course in a very short time as the leadership of the partnership becomes a quagmire of conflicting opinions, egos, and personalities. When the systems are defined, agreed upon, and implemented, the likelihood of things staying on track is greatly enhanced.

Recognizing the strengths and weaknesses of your potential partners and understanding the leadership role (if any) that each partner is to have in the overall scheme of the business structure will ensure the greatest opportunity for success. The selection of the right leadership structure and the systems that will be implemented to run the organization will likely have the greatest impact on the future success of the business, given that it will have massive influence on the level of trust and transparency within the organization, the level of open communication that is enjoyed and ultimately the core functionality of the executive team. Get this piece right and you can survive almost anything. Get it wrong and the partnership is doomed. Do not overlook its importance and the impact of its long-term effects.

6. Building a Legal Foundation

To put your business in good stead, seek out a good attorney that understands the veterinary landscape. You would be surprised how specialized this area truly is. Considering the complexity of non-compete provisions, the valuation methodology you select for the sale of future interests in the company, and the restrictions on transferability that are considered industry norms for veterinary medicine, you will want to work with someone who understands the industry. Below is a checklist of the key legal elements that will position your practice well.

- Know who your attorney is representing. Does he represent you? You and your partner combined? The organization? Or all three? And are you happy with that? Ask your attorney to describe the representation from the outset. It is a common mistake for all partners to

consider the attorney as “their lawyer” only to learn later that he was really looking out for the interests of one stakeholder. What is more, you do not want to be paying the bill for someone who is not looking out for your interests. Make sure there is an appropriate engagement letter that spells out the representation so that you have assurance that your personal interests are being looked after by a legal professional.

- Make sure you get input on entity selection, giving consideration to how the partnership will be taxed. You will want to consult your tax advisor to give you guidance in this area to avoid any unnecessary double taxation. Consider whether you wish to be taxed at the entity level or flow through to the partners individually? Is this the best tax structure for you personally? Would you rather see it handled differently? Remember, at the beginning is the time to ask questions and voice concerns. Once things are written and signed, although usually they are capable of being amended, it is always more difficult and more costly to rewrite the rules.
- Understand the significance of your corporate formalities. LLCs vs corporations, vs partnerships, there are different requirements for each. Failure to adhere to these agreed-upon formalities can be problematic, particularly in the event of a lawsuit.
- You will also need to openly agree upon what type of corporate formalities will be accepted. The frequency of meetings, the place and method of notification of meetings, and what will be expected at the annual meeting.
- How will the partnership be managed? Member managed? Manager managed? Board managed? There are different rules and different forms of management based on the state that you live in. Be sure you read this carefully as you want to make sure your initial understanding is what is being agreed to on paper. Designate who has rights to what information and how that information can be accessed.
- Voting percentages are key to management and control. If yours is meant to be an equal partnership with each partner having equal say in all matters, make sure this is adequately described. At the same time, be sure that along with the percentage of ownership described, the contribution that merits that percentage of ownership needs to be detailed with specificity. Avoid any generalized terms or vague language when it comes to initial contributions. Finally, when addressing voting rights make sure you understand if all decisions will be the determination of the manager and that you understand who the manager(s) are. Know what types of decisions require

a majority, a supermajority, and unanimous consent. Many partnerships start out as two partners in a 50/50 deal, but soon expand to include more partners over time. The more complete and correct your agreement is in the beginning, the less chance for errors and the lower costs you will incur regarding necessary changes to your company agreement.

- How will we address a deadlock in management? In a 50/50 partnership, how do we move pass a voting tie? Mediation? Coin toss? Turtle race?
- Understand capital contributions. What is considered capital and who will contribute what and when? Will capital calls be permitted? Who can make a capital call? What are the triggering events? How much more money can you be required to come up with? And in what time-frame? Will the partnership be maintaining capital accounts?
- Spell out what you expect in terms of financials and the frequency with which you expect to review them, (P&L, statement of cash flows, and balance sheets). Also, discuss what accounting method you will be using (cash vs accrual).
- How distributions will be addressed, tax distributions, limitations on distributions. These are all questions that must be answered as you entertain your partnership.
- Make sure your agreement has an indemnification clause stating that members are indemnified by company for acts done in good faith within their authority.
- Transfer of ownership is of utmost importance. What rules will your partnership have regarding transferability? And what triggering events should be considered (death, divorce, etc.)? Include provisions for first rights of refusal along with appropriate time periods, methodology, spousal consents acknowledging the arrangement.
- How will the practice be valued? Is there an agreed upon price? If so, how long will it hold as being an accurate value for the practice? Beyond that, or in absence of, how will value be determined? By whom? And in the event of a sale, what payment terms will be acceptable? The more of this you have ironed out in your partnership agreement, the less likely there will be a significant dispute about the methodology when the time arrives to make that determination.
- Include important non-compete provisions to protect the practice from future competition should a partner sell his interest and then later decide to set up shop in the vicinity.
- Determine who has the authority to amend the agreement, and how that amendment can be made.

- In the event of a dispute, what resolution measures will be considered? Will you choose litigation, mediation, arbitration, or arm wrestle? Do you know the difference?
- Make sure you include language as to who can consent to winding up and other triggering factors, such as bankruptcy or judicial decree that may bring about the end of business for a given entity.

There are many details to consider, which is why having a good attorney well versed in industry standards and norms is of benefit to any potential partnership in the veterinary space. Your interest in a veterinary practice is your livelihood throughout your professional career and is likely your retirement plan as well. Treat it carefully and protect it vigilantly from a legal standpoint. Be diligent in your compliance with your organizational bylaws. By participating in making the rules, not only do you know what the rules are, but you have an opportunity to be heard on the front end of any organization issue while still in the honeymoon phase. Once you sign them as an owner and likely and officer or manager, they are truly your promise to the company that you will carry the torch meticulously on behalf of the welfare of the organization. Your commitment to the acknowledgments you make will bear dividends down the road when you position yourself to accept distributions, bring on new partners, and sell some or all of your interest in the company.

7. Conclusion

In today's world diversity is rather en vogue. The more different something is, the more it fits with society's expectations. Not everyone sees the world the same and while our society celebrates this as a good thing, it is not necessarily great advice for business partners. Yes, we are all individuals with different viewpoints, and not only do we not see it the same today, but our viewpoint changes over the years. What we perceive as being important today may become secondary to other things in the future. Aligning yourself with an organization or individual(s) with "like" values, carefully selecting a leadership/governance structure and implementing a solid legal foundation will collectively achieve one thing ... it will establish the expectations. Expectations communicated and effectively managed, will lead to prosperity.

As important as you knowing why you are interested in a partnership and what your values and perceptions are with regard to the partnership is the obligation to communicate these things to your partner(s) so that they know where you are coming from, why you are involved in the deal, and to make sure that you understand their viewpoint in return.

It has been said that good fences make good neighbors. Fences establish boundaries; the expectation that you can come this far ... but no further. As you

consider your values and communicate them, you are establishing these expectations. As you explore the leadership structure of the partnership and the potential systems that will be employed, again the expectations are being made known. Even if you do not get your way all the time, it is important to ask these questions and have these conversations at the outset, to avoid a miscommunication down the road that can lead to mistrust. Bear in mind those leadership pitfalls of the Peter principle, founders syndrome, and the importance of having and management systems as described in the *E-Myth*. As these areas are explored and discussed, you will unveil a multitude of important factors to be considered as you establish your legal foundation, which will lay the groundwork for many of the partnership expectations.

When the key areas I have outlined have been discussed and decisions made after thoughtful consideration of everyone's view point, you will have a much greater chance at having a successful partnership venture.

Perhaps the most famous case in demonstrating the power of expectations is that of the "experimenter expectancy effect" as was performed by Dr. Rosenthal in 1963 when he took two groups of rats and examined the ability of each group to learn to navigate through a maze. But it was not the rats that were being examined, rather, it was the "examiner" and their influence on the outcome based on what they had been led to believe. Rosenthal had two groups of students test the rats, wrongly informing them that one group of rats had been specially bred to be "maze dull" and the other was "maze bright." In reality, all rats were standard lab rats, and were randomly assigned to the "dull" and "bright" conditions. The results showed that the rats labeled as "bright" learned the mazes more quickly than those labeled as "dull."⁵ Apparently, students had unconsciously influenced the performance of their rats, depending on what they had been told.

The lesson in this experiment is that the expectation determined the result. It is no different in partnerships. When expectations are defined and communicated, they are more likely to be met. When partners know what to expect, when they communicate with transparency, when they do not surprise one another, they better position themselves to expect success.

Acknowledgments

The contents of this abstract are intended to convey general information only and not to provide legal advice or opinions, nor is it intended as advertising or as solicitation for legal services. This abstract should not be construed as, and should not be relied upon for, legal advice in any particular circumstance or fact situation. An attorney should be contacted for advice on specific legal issues.

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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Financial Statements

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1. Introduction

The purpose of this paper is to give some general information regarding financial statements and the information they can provide about a practice. This paper will provide an overview of financial statements using a fictitious practice. This practice has been named Mega Valley Equine Hospital (MVEH). The actual numbers come from the combination of over 30 equine practices from around the country so the numbers and trends are representative of what can have been seen in any practice. There has been, in no way, an attempt to verify the accuracy of the information and it has simply been used in the computations and analysis.

Financial reporting refers to the way companies show their financial performance to investors, creditors, and other interested parties by preparing and presenting financial statements. Financial reporting summarizes a practice's operating activities (the practice's ordinary business), investing activities (purchasing, selling, and disposing of long-term assets), and financing activities (raising and repaying capital). The role of financial-statement analysis is to use the information in a company's financial statements, along with other relevant information, to make economic decisions. Stakeholders use financial statement data to evaluate a company's past performance and current financial position to form opinions about the company's ability to earn profits

and generate cash flow in the future. Generally, financial-statement analysis uses the following financial statements: income statement, statement of cash flows, and balance sheet.

This paper is organized based on the financial statements. There is a separate section for each of the basic financial reports contained within a comprehensive set of financial statements, Income Statement, Cash Flow Statement, and Balance Sheet. Each separate report section (Income Statement, Cash Flow Statement, and Balance Sheet) has some general information about what these reports contain and how they can be used to manage your business. After the financial statements reports, it will provide information regarding certain financial ratios created from the financial statements. These ratios are calculated based on the Income Statement and Balance Sheet.

Finally, this paper contains an analysis of the value of MVEH. There has been no examination of the data for accuracy, and therefore no one can attest to the information provided.

2. Income Statement

The income statement reports on the financial performance of your practice over a period of time. Investors examine the practice's income statement for valuation purposes while lenders examine the income statement for information about the practice's ability to make the promised interest and principal payments

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on its debt. The basic income statement equation is: Revenue – Expenses = Net Income. Therefore, the elements of the income statement include revenues, expenses, and gains and losses.

Revenues are inflows from delivering or producing goods, rendering services, or other activities that constitutes the practice’s ongoing major or central operations. Revenues are categorized by sales, gains, and investment income. Expenses are outflows from delivering or producing goods and services that constitute the practice’s ongoing major or central operations. Expenses are categorized by cost of goods sold; selling, general, and administrative expenses; depreciation and amortization; tax expense; interest expense; and losses. Gains and losses are increases and decreases in equity or net assets from peripheral or incidental transactions outside the practice’s primary business activities. The income statement can be summarized as follows:

Gross Revenue	
(Cost of Goods Sold)	
Gross Profit	
(Operating Expense)	
Operating Profit	
(Interest Expense)	
Income Before Tax	
(Tax Expense)	
Net Income	

Gross profit is the amount that remains after the direct costs of producing a product or service are subtracted from revenue. By subtracting operating expenses, such as selling, general and administrative expenses, and depreciation from gross profit results in operating profit. By subtracting interest expense and income taxes from operation profit results in the practice’s net income. Under the accrual method of accounting, revenue is recognized when earned and expenses are recognized when incurred. The important point to remember is that accrual accounting does not necessarily coincide with the receipt or payment of cash. Consequently, practices can manipulate net income by recognizing revenue earlier or later or by delaying or accelerating the recognition of expenses.

3. Cash Flow Statement Analysis

Given that the income statement is usually based on the accrual method of accounting, net income may not represent cash generated from operations. A company may be generating positive and growing net income, but may be heading for insolvency because insufficient cash is being generated from operating activities. The cash flow statement pro-

vides information beyond that available from the income statement, which may be based on accrual, rather than cash accounting.

The cash flow statement reports on the practice’s cash receipts and cash payments during an accounting period. It provides information about a company’s operating, investing, and financing activities and an understanding of the impact of accrual accounting events on cash flows. The cash flow statement provides insight to assess the practice’s liquidity, solvency, and financial flexibility. It helps to determine whether regular operations generate enough cash to sustain the business, if enough cash is generated to pay off existing debts as they mature, if the practice is likely to need additional financing, whether unexpected obligations can be met, and whether the practice can take advantage of new business opportunities as they arise.

Items on the cash flow statement come from income statement items and balance sheet items. A practice’s cash receipts and payments are classified on the cash flow statement as either operating activities, investing activities, or financing activities.

Cash flow from operating activities consists of the inflows and outflows of cash resulting from transactions that affect a practice’s net income. Examples of operating activity inflows include cash collected from customer and interest and dividends received. Examples of operating activity outflows include cash paid to employees and suppliers, taxes paid, interest paid, and cash paid for other expenses.

Cash flow from investing activities consists of the inflows and outflows of cash resulting from the acquisition or disposal of long-term assets and certain investments. Examples of investing activity inflows include sales proceeds from fixed assets and principal received from loans made to others. Examples of investing activity outflows include acquisitions of fixed assets and loans made to others.

Cash flow from financing activities consists of the inflows and outflows of cash resulting from transactions affecting a practice’s capital structure. Examples of financing activity inflows include proceeds from issuing stock and principal amounts of debt issued. Examples of financing activity outflows include principal paid on debt and dividends paid to shareholders.

The cash flow statement reconciles the beginning and ending balances of cash over an accounting period. The change in cash is a result of the practice’s operating, investing and financing activities as follows:

Operating cash flow	
+ Investing cash flow	
+ Financial cash flow	
Change in cash balance	
+ Beginning cash balance	
Ending cash balance	

It is important to understand that net income based on accrual accounting is not the same thing as cash earnings. When the timing of revenue or expense recognition differs from the receipt or payment of cash, it is reflected in changes in balance sheet items. Just keep in mind that a practice's balance sheet, income statement, and cash flow statement are all related.

4. Balance Sheet Analysis

Although the income statement presents a picture of a practice's economic activities over a period of time, the balance sheet reports the practice's financial position at a point in time. The balance sheet is important to investors and lenders alike. The balance sheet consists of three elements: assets, liabilities, and owner's equity. Transactions are measured so that the fundamental accounting equation holds: $\text{Assets} = \text{Liabilities} + \text{Owner's Equity}$ or $\text{Assets} = \text{Liabilities} + \text{Contributed Capital} + \text{Ending Retained Earnings}$. Therefore, changes in the balance sheet during an accounting period are reflected in the income statement, the cash flow statement, and the statement of owner's equity.

Assets are probable current and future economic benefits obtained or controlled by a particular entity as a result of past transactions or events. They are a practice's economic resources. Assets can be created by operating activities (i.e., generating net income), investing activities (i.e., purchasing equipment), and financing activities (i.e., borrowing). Examples of assets include cash and cash equivalents, accounts receivables, inventory, prepaid expenses, property plant and equipment, pension assets, and intangible assets. Furthermore, assets are classified as current assets, fixed assets, other assets such as intangible assets, and long-term accounts receivables.

Liabilities are probable future economic costs and creditor claims on the company's resources. They are created by financing activities (i.e., borrowing) and operating activities (i.e., generating net income). Liabilities arise from present obligations of a particular entity to transfer assets or provide services to other entities in the future as a result of past transactions or events. Examples of liabilities include accounts payable, short-term note payable, unearned revenue, income taxes payable, and long-term notes payable. Furthermore, liabilities are classified as current liabilities and long-term liabilities.

Owner's equity is the residual interest in the net assets of an entity that remains after deducting liabilities. Equity is created by financing activities and by operating activities. Owner's equity consists of capital contributed by the practice's owners and the cumulative earnings the practice has retained. Examples of owner's equity includes contributed capital, par value of common stock, additional paid in capital, and retained earnings.

5. Financial Ratio Analysis

Financial ratios are based on backward-looking data to provide insights into the financial relationships that are useful in forecasting future earnings and cash flow, information about the financial flexibility of the practice, and a means of evaluating management performance internally and to its peers. Financial ratios are not useful when viewed in isolation, compared with other companies using different accounting methods and there may be difficulty in locating comparable ratios when analyzing companies that operate in multiple industries. Conclusions cannot be made from viewing one set of ratios. Ratios must be viewed relative to one another over time, between companies, or relative to benchmark values. Judgment is required. Determining the target or comparison value for a ratio is difficult and may actually be some range of acceptable values rather than a single target value.

Asset Ratios

Inventory Turnover Ratio

This ratio measures the number of times, on average, inventory is sold during the period. Its purpose is to measure the liquidity of the inventory. A high number suggests a greater sales efficiency and should be compared with industry standards.

Fixed-Asset Turnover Ratio

The fixed-asset turnover ratio measures the company's effectiveness in generating sales from its investments in plant, property, and equipment. If the fixed-asset turnover ratio is low compared with the industry, it means that sales are low or the investment in plant and equipment is too much.

Total Assets Ratio

The total asset ratio represents the amount of revenue generated by a company as a result of its assets on hand. It measures how efficiently a company is operating. A low ratio suggests that the total assets of the business are not providing adequate revenue.

Asset-to-Equity Ratio

The asset-to-equity ratio is a measure of financial leverage and long-term solvency. A high ratio suggests the practice may be overall leveraged.

Profitability Ratios

Return-on-Assets Ratio

Return on assets is a key ratio of profitability, indicating how efficiently a practice's assets are employed. A low ratio suggests that earnings are low for the amount of assets.

Return-on-Equity Ratio

Return on equity is a profitability ratio measuring how well equity capital is used. The higher the ratio, the greater the return on the capital invested.

Profit Margin Ratio

Profit margin measures how much out of every dollar of sales a company keeps in earnings. A higher profit margin suggests a more profitable company that has better control over its costs compared with its competitors.

Basic Earnings Power Ratio

The basic earnings power ratio evaluates the effectiveness of a practice's operation by measuring the basic profitability of assets by excluding interest and tax expense. This ratio should be examined in conjunction with turnover ratios to help pinpoint potential problems regarding asset management.

Debt Ratios

Total Debt Ratio

The total debt ratio is a measure of a company's financial leverage. A high ratio generally means that a company has been aggressive in financing its growth with debt.

Interest Coverage Ratio

The interest coverage ratio is a measure of the number of times a company could make the interest payments on its debt with its earnings before interest and taxes. The lower the ratio, the higher the practice's debt burden and the greater the possibility of bankruptcy or default.

Debt/Equity Ratio

The debt/equity ratio suggests what proportion of equity and debt that the company is using to finance its assets. A ratio greater than one means assets are mainly financed with debt, less than 1 means equity provides a majority of the financing.

Capitalization Ratio

The capitalization ratio measures the debt component of a practice's capital structure to support a company's operations and growth. The higher the ratio, the greater amount of leverage the practice is taking on. Capitalization ratios need to be evaluated over time, and compared with other data and standards.

Efficiency Ratios

Cash Turnover

The cash turnover ratio suggests a practice's efficiency in its use of cash for generation of sales revenue. The higher the number, the greater efficiency a practice is displaying cash.

Days Sales in Account Receivables

The days' sales in account receivables ratio measures how many days it takes to collect account receivables. The lower the ratio, the more efficient a practice is at collecting account receivables.

Account Receivables Turnover

Account receivables turnover is a measure of the practice's ability to collect account receivables. The higher the ratio, the more efficiently a practice is at collecting account receivables.

Inventory Turnover in Days

The inventory turnover ratio represents how many times inventory was used and then again replaced. A low ratio suggests that inventories are not being managed efficiently.

Days Sales in Inventory

The day sales in inventory ratio measure how many days it takes to turn inventory in sales. The lower the ratio, the more efficiently a practice is at converting inventory into sales.

6. Practice Valuation Analysis

The purpose of this portion of the paper is to provide an analysis of the value of MVEH. This paper is designed to describe the approach, illustrate the computations, and to provide a basis of the findings based upon the facts and assumptions used in making a conclusion. The facts regarding MVEH have not been reviewed, verified, or audited in any way.

This report is not intended to be an appraisal of the value of a practice. We have not appraised a practice, nor have we gathered sufficient information in order to prepare an appraisal of a practice. In fact, we are not appraisers, and do not, in the normal course of our business prepare appraisals. Therefore, this report is designed to simply illustrate the potential value of the cash flows generated by a business.

7. Computation Methodology

There are many ways to analyze value. One can value all the assets of a business and subtract the outstanding liabilities and consider that value. With this approach one must attempt to determine the value of the goodwill or "blue sky" (because this too is an asset of the business) of the business in order to approximate the value of the business. Valuing goodwill is a difficult thing to do that requires several subjective decisions upon which reasonable people could disagree.

Another more objective way to value a business is to simply multiply some objective number, whether that number is Earnings Before Interest Taxes Depreciation and Amortization (EBITDA), gross revenue, gross profit, or net income by a rather subjective multiplier. These multipliers vary by industry and are typically derived from historical information based upon historical sales prices for similar businesses. Although this might be a relatively easy calculation, this approach tends to be historical in its perspective. It does not take into account how much the business might be making in the future. Because of its relative ease in calcu-

lation, this tends to be the most widely used method of estimating a closely held business.

For businesses that are widely held and have numerous buy/sell transactions, historical transactions can help one determine current value. This is most true in the public markets. Because publicly held companies are so widely held there tend to be multiple transactions every day, and even every minute. Because all of these transactions are between a willing buyer and a willing seller and are all at “arm’s length,” these transactions create the best view of a company’s worth. Unfortunately, in your business you do not have any public companies and therefore this is not a viable method of valuation.

The US Internal Revenue Service (IRS) has also developed its own method of valuing a business. In IRS Revenue Ruling 59-60 the IRS states that the value of a business is “the price at which the property would change hands between a willing buyer and a willing seller when the former is not under any compulsion to buy and the latter is not under any compulsion to sell, both parties having reasonable knowledge of relevant facts.” This definition has withstood numerous court challenges and remains the IRS standard. The problem is in the calculation of this value. Although you would be hard pressed to dispute the premise of this definition, the definition provides very little specific guidance as to how to determine value when there is a lack of a “willing buyer and a willing seller.” We believe the best way to determine what a “willing buyer and a willing seller” would pay for a business is based on the profitability of the company and the cash flow created by the business.

8. Discounted Cash Flow Analysis

The best way to analyze the value of any business is based on the money that can be made by that business. There are many things that determine how much money a particular business can make and thereby its value. The most basic aspect of making money is cash flow. This approach to valuation is known as discounted cash flow analysis.

The cash flow of a business is determined by taking the net income of a business and adjusting for the noncash items contained within that net income number. Depreciation is one of the most obvious noncash charges against income that must be added back to determine net cash flow from a business. There are several others including adjusting the net income, if the business reports net income on an accrual basis, for changes in accounts receivable and accounts payable and other deferred or accrued items of income and expense. Another adjustment relates to capital expenditures. Cash flow should be reduced to the extent the business takes a portion of its profits and spends that money on capital expenditures such as equipment, real estate, or other assets. Future debt principal repayment will also reduce the amount of cash available to be distributed as a return on equity.

Once a business has determined its current cash flow it must consider how that cash flow is going to grow over time. Once that is determined you can project how much cash flow a particular business will generate over time. Obviously one would not pay the same for cash created 10 years from now that they would pay for cash created today. These future cash flows must be discounted back to today’s dollars.

This is done by taking each future cash flow that the business will create and determining how much money that cash flow in the future is worth today. Another way to think about this is to consider how much money one would have to put to work today, at a given interest rate, for that money to be worth the cash flow from the business in that future year.

The “interest rate” one would apply today to those future cash flows is also known as the discount rate. The riskier the business, the higher the discount rate. Another way to state this is, the discount rate is equal to the risk that the future cash flows of the business will not be realized.

There is a readily accepted formula for determining the discount rate in most situations (Discount Rate = Risk Free Rate + Beta (Market Return – Risk Free Rate)). There are three components to the formula.

First is typical market return. We have used 10% in our calculations for market return. Over an extended period of time, the stock market has returned an average of approximately 10%. This rate of return in the stock market has declined during the last few years but we feel 10% is still an accurate representation of market return. From this market return of 10% you subtract the risk-free rate of return. Currently, the 10-year US Treasury bond is yielding approximately 2.0%. This results in an 8% risk-adjusted rate of return. You then multiply this risk-adjusted rate of return by the Beta of the individual company. Beta is a factor ranging from 0 to 2 and is designed to measure how much more risk a particular stock has, when compared with an index, for instance, the S&P 500 (0 being no risk in the market, 1 being average risk in the stock market, and 2 being the most risk possible in the stock market). We have assigned a Beta of 1.04, which is the beta for VCA, Inc, a publicly traded animal health care company. In order to get the final discount, you must multiply the risk-adjusted rate of return (8%) by the Beta of 1.04 and add back the risk-free rate of 2%, resulting in a discount rate of 10.32%. This seems reasonable as an overall measure of risk for your business. The other way to consider this discount rate is asking if you would be willing to buy your business if you knew you would receive a 10.32% rate or return on that investment?

Finally, the IRS allows you to apply a lack of marketability discount for closely held businesses. The discount for lack of marketability is an amount or percentage deducted from the value of an ownership interest to reflect absence of marketability.

A primary concern for driving this price reduction is that, over the uncertain timeframe required to complete a sale, the final sale price becomes less certain and with it a decline in value is quite possible. Accordingly, a prudent buyer would want a discount for acquiring such an interest to protect against value loss in a future sale scenario. For your price, we used a 40% lack of marketability and illiquidity discount.

9. Risk Factors to This Valuation

The risk factors that could affect the value of your practice include, but are not limited to, the possible loss and replacement of a top-producing veterinarian, the cost to maintaining efficiencies in practice operations from a change in ownership and leadership of the practice, and maintaining cost efficiencies in practice operations as your practice expands or contracts.

10. Limitations on This Valuation

Like any valuation analysis, the discounted cash flow analysis has its limitations. It is rather sensitive to variations in the data inputs. If any of the

inputs are materially misstated, the resulting valuation will also be misstated. Due to the limited information received from the various practices, very limited information on capital expenditures is reflected, so the valuation may be overstated due to the capital expenditures within the business. Typically, cash flow would be reduced for money spent on new equipment.

Discounted Cash Flow analysis does not take into account certain contingencies such as lawsuits not known, changes in staff compensation, governmental reviews and investigations, and other outside influences. Anyone should be aware of these items and should factor these items into overall conclusion regarding the value of a practice.

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.

11. Appendix

**Mega Valley Equine
Hospital**

**Financial Statement
Packet**

THE BUSINESS OF PRACTICE: FINANCIAL BASICS FOR A SUCCESSFUL PRACTICE

Mega Valley Equine Hospital								
Income Statement								
Jan. - Dec. 2014	% of Total Income	Jan. - Dec., 2015	% of Total Income	Jan. - Dec., 2016	% of Total Income	Average	Industry	
100,357,956	100.00%	103,901,890	100.00%	107,180,281	100.00%	100.00%		Income
	0.00%		0.00%		0.00%	0.00%		Drug Company Rebates
	0.00%		0.00%		0.00%	0.00%		Fees
	0.00%		0.00%		0.00%	0.00%		H&S Lab Income
	0.00%		0.00%		0.00%	0.00%		Other Income
100,357,956	100.00%	103,901,890	100.00%	107,180,281	100.00%	100.00%	100.00%	Total Income
(1)								Cost of Professional Services
308,228	0.31%	317,632	0.31%	327,239	0.31%	0.31%	0.32%	Animal & Medical Waste Disposal
20,424,001	20.35%	21,130,777	20.34%	21,782,448	20.32%	20.34%	20.33%	Drugs & Supplies
2,042,280	2.03%	2,112,068	2.03%	2,174,568	2.03%	2.03%	1.97%	Field Service Costs (Vehicle Fuel, Maintenance, Insurance, or Mileage)
597,522	0.60%	618,305	0.60%	640,042	0.60%	0.60%	0.62%	Hospitalization (Feed, Bedding, Isolation, Biosecurity, Stall Waste Disposal, Supplies)
1,144,059	1.14%	1,190,312	1.15%	1,240,767	1.16%	1.15%	1.09%	Imaging (Radiology, Ultrasound, Endoscopy, MRI, Scintigraphy, Catscan)
1,873,019	1.87%	1,936,725	1.86%	1,995,339	1.86%	1.86%	1.88%	Laboratory (In House & Reference)
874,555	0.87%	908,423	0.87%	937,755	0.87%	0.87%	0.91%	Other - COPS
	0.00%		0.00%		0.00%	0.00%		Outside Services
27,263,664	27.17%	28,214,242	27.15%	29,098,159	27.15%	27.16%	27.12%	Total Cost of Professional Services
73,094,292	72.83%	75,687,648	72.85%	78,082,123	72.85%	72.84%	73.91%	Gross Profit
593,239	0.59%	614,089	0.59%	635,397	0.59%	0.59%	0.62%	Administrative Expenses
250,089	0.25%	257,204	0.25%	263,604	0.25%	0.25%	0.27%	Advertising and Promotion
144,812	0.14%	149,402	0.14%	153,083	0.14%	0.14%	0.15%	Bank Charges
1,326,671	1.32%	1,374,936	1.32%	1,422,624	1.33%	1.32%	1.34%	Charitable Contributions
366,984	0.37%	380,474	0.37%	394,761	0.37%	0.37%	0.38%	Collection Expenses (Bad Debt)
357,994	0.36%	369,218	0.36%	379,971	0.35%	0.36%	0.34%	Consultant Fees
173,731	0.17%	178,673	0.17%	183,355	0.17%	0.17%	0.17%	Dues, Licenses and Subscriptions
577,130	0.58%	598,836	0.58%	616,067	0.57%	0.58%	0.59%	Miscellaneous Expenses
371,343	0.37%	384,829	0.37%	398,550	0.37%	0.37%	0.36%	Office Supplies, Meals & Expenses
938,890	0.94%	971,094	0.93%	997,196	0.93%	0.93%	0.97%	Postage Expense
318,584	0.32%	332,780	0.32%	347,235	0.32%	0.32%	0.33%	Professional Fees
34,329	0.03%	35,517	0.03%	36,776	0.03%	0.03%	0.03%	Sales and Miscellaneous Taxes
5,453,797	5.43%	5,647,053	5.43%	5,828,619	5.44%	5.44%	5.55%	Uniforms
								Total Administrative Expense
585,849	0.58%	608,366	0.59%	627,667	0.59%	0.58%	0.61%	Facility and Equipment Costs
101,248	0.10%	104,413	0.10%	107,514	0.10%	0.10%	0.11%	Computer Related Costs
253,840	0.25%	258,906	0.25%	264,210	0.25%	0.25%	0.26%	Equipment Expense
697,367	0.69%	716,962	0.69%	738,925	0.69%	0.69%	0.70%	Other - Real Estate and Equipment Costs
336,300	0.34%	349,407	0.34%	362,660	0.34%	0.34%	0.34%	P&C Insurance Expense
5,908,527	5.89%	6,029,021	5.80%	6,150,643	5.74%	5.81%	5.65%	Property Taxes
970,175	0.97%	1,005,394	0.97%	1,039,927	0.97%	0.97%	0.98%	Real Estate Rental Expense
180,518	0.18%	188,653	0.18%	197,604	0.18%	0.18%	0.17%	Repairs & Maintenance Expense
707,340	0.70%	730,766	0.70%	752,852	0.70%	0.70%	0.70%	Service Contracts & Maintenance Agreements
647,228	0.64%	669,970	0.64%	692,629	0.65%	0.65%	0.66%	Telephone Expense
10,388,393	10.35%	10,663,860	10.26%	10,934,630	10.20%	10.27%	10.18%	Utility Expense
								Total Facility and Equipment Costs
1,220,432	1.22%	1,263,386	1.22%	1,303,087	1.22%	1.22%	1.19%	Depreciation Costs
								Depreciation Expense
1,220,432	1.22%	1,263,386	1.22%	1,303,087	1.22%	1.22%	1.19%	Total Depreciation Costs
3,540,378	3.53%	3,690,231	3.55%	3,821,290	3.57%	3.55%	3.66%	Payroll and Employee Costs
10,832,796	10.79%	11,227,426	10.81%	11,587,823	10.81%	10.80%	11.09%	Compensation - Administrative
1,046,597	1.04%	1,087,240	1.05%	1,129,204	1.05%	1.05%	9.70%	Compensation - Associate DVMs
1,009,845	1.01%	1,041,782	1.00%	1,075,119	1.00%	1.00%	0.86%	Compensation - DVM Officers
10,182,337	10.15%	10,534,102	10.14%	10,869,422	10.14%	10.14%	0.99%	Compensation - Intern DVMs
888,999	0.89%	914,460	0.88%	940,911	0.88%	0.88%	1.28%	Compensation - Other (To Family (Children))
1,279,170	1.27%	1,311,302	1.26%	1,257,848	1.17%	1.24%	1.46%	Compensation - Other Support Staff (To Dr. Black's Wife)
1,363,795	1.36%	1,417,399	1.36%	1,465,003	1.37%	1.36%	5.59%	Compensation - Owner/Management
5,696,148	5.68%	5,910,458	5.69%	6,115,585	5.71%	5.69%	1.04%	Compensation - Technician
281,467	0.28%	291,521	0.28%	301,302	0.28%	0.28%	0.29%	Compensation-Barn Crew
872,692	0.87%	905,500	0.87%	930,678	0.87%	0.87%	0.85%	Continuing Education Costs
3,587,053	3.57%	3,706,817	3.57%	3,811,198	3.56%	3.57%	3.60%	Contract Labor Expense
379,923	0.38%	396,304	0.38%	409,889	0.38%	0.38%	0.40%	Employee Benefits Expenses
115,958	0.12%	119,984	0.12%	123,042	0.11%	0.12%	0.13%	Officer Insurance Expense
2,562,830	2.55%	2,653,982	2.55%	2,739,587	2.56%	2.55%	2.54%	Other - Payroll & Employee Costs
117,294	0.12%	121,768	0.12%	126,388	0.12%	0.12%	0.12%	Payroll Tax Expense
519,573	0.52%	539,883	0.52%	559,287	0.52%	0.52%	0.51%	Seminars and Meetings
375,737	0.37%	388,241	0.37%	399,627	0.37%	0.37%	0.38%	Travel, Meals & Entertainment Expense
								Workers Compensation
44,652,592	44.49%	46,258,399	44.52%	47,663,203	44.47%	44.49%	44.49%	Total Payroll Costs
61,715,214	61.50%	63,832,698	61.44%	65,729,539	61.33%	61.42%	67.53%	Total Expense Before Interest Expense
11,379,077	11.34%	11,854,949	11.41%	12,352,583	11.53%	11.42%	6.38%	Net Ordinary Income
67,401	0.07%	67,401	0.06%	67,401	0.06%	0.06%	0.07%	Other Expenses
255,299	0.25%	186,149	0.18%	126,958	0.12%	0.18%	0.14%	Amortization Expense
322,700	0.32%	253,550	0.24%	194,359	0.18%	0.25%	0.21%	Interest Expense
								Total Other Expenses
11,056,377	11.02%	11,601,399	11.17%	12,158,224	11.34%	11.18%	11.28%	Net Income
12,599,510	12.55%	13,118,335	12.63%	13,655,670	12.74%	12.64%	12.68%	EBITDA

Mega Valley Equine Hospital		
Cash Flow Statement		
Jan. - Dec. 2015	Jan. - Dec. 2016	
11,612,577	12,158,224	OPERATING ACTIVITIES
		Net Income
(107,270)	(122,370)	Adjustments
(6,650)	(6,741)	Accounts Receivable
55,823	43,299	Inventory on Hand
-	-	Other Current Assets
-	-	Goodwill
-	-	Other Assets
67,048	67,048	Goodwill - Accum. Amortization
-	-	Accumulated Amortization
(18,675)	22,879	Accounts Payable
(333,852)	(57,737)	Other Current Liabilities
1,263,386	1,303,087	Depreciation
12,532,387	13,407,689	Net Cash Provided by Operating Activities
		INVESTING ACTIVITIES
		Cash Paid For
(12,500)	(31,500)	Building and Improvements
(42,500)	(32,000)	Computer Software & Equipment
(110,000)	(176,500)	Office Furniture & Equipment
(1,242,500)	(1,052,000)	Professional Equipment
(360,000)	(285,000)	Vehicles
(1,767,500)	(1,577,000)	Net Cash Provided by Investing Activities
		FINANCING ACTIVITIES
(411,432)	(259,332)	Equipment - Note/Lease Payable
(576,857)	(514,247)	Other - Note/Lease Payable
(363,666)	(277,293)	Vehicle - Note/Lease Payable
-	-	Other Long Term Liabilities
(9,286,281)	(9,503,942)	Owner Distribution
(10,638,236)	(10,554,814)	Net Cash Provided by Financing Activities
126,652	1,275,875	Net Cash Increase for Period
5,708,646	5,835,297	Cash at Beginning of Period
5,835,297	7,111,173	Cash at End of Period

Mega Valley Equine Hospital			
Balance Sheet			
12/31/2014	12/31/2015	12/31/2016	
			Current Assets
5,708,646	5,835,297	7,111,173	Cash
			Accounts Receivable
5,977,465	6,084,734	6,207,104	Accounts Receivable
5,977,465	6,084,734	6,207,104	Total Accounts Receivable
			Other Current Assets
2,409,681	2,416,331	2,423,072	Inventory on Hand
1,418,084	1,362,261	1,318,962	Other Current Assets
3,827,765	3,778,592	3,742,034	Total Other Current Assets
15,513,875	15,698,624	17,060,311	Total Current Assets
			Fixed Assets
4,915,954	4,928,454	4,959,954	Building and Improvements
1,635,176	1,677,676	1,709,676	Computer Software & Equipment
2,612,560	2,722,560	2,899,060	Office Furniture & Equipment
24,975,081	26,217,581	27,269,581	Professional Equipment
6,995,766	7,355,766	7,640,766	Vehicles
233,566	233,566	233,566	Other Fixed Assets
41,368,103	43,135,603	44,712,603	Total Gross Assets
(33,588,865)	(34,852,251)	(36,155,337)	Accumulated Depreciation
7,779,238	8,283,352	8,557,265	Total Fixed Assets
			Other Assets
1,800,969	1,800,969	1,800,969	Goodwill
1,010,942	1,010,942	1,010,942	Other Assets
(1,353,024)	(1,420,072)	(1,487,120)	Goodwill - Accum. Amortization
(490)	(490)	(490)	Accumulated Amortization
1,458,398	1,391,350	1,324,302	Total Other Assets
24,751,511	25,373,325	26,941,877	Total Assets
			Current Liabilities:
2,975,922	2,957,247	2,980,126	Accounts Payable
3,173,303	2,839,451	2,781,714	Other Current Liabilities
6,149,225	5,796,698	5,761,840	Total Current Liabilities
			Long Term Liabilities
1,080,873	669,441	410,108	Equipment - Note/Lease Payable
3,028,982	2,452,125	1,937,879	Other - Note/Lease Payable
982,568	618,902	341,609	Vehicle - Note/Lease Payable
17,502	17,502	17,502	Other Long Term Liabilities
5,109,924	3,757,970	2,707,098	Total Long Term Liabilities
11,259,149	9,554,668	8,468,938	Total Liabilities
			Capital
-	-	-	Capital Stock
2,330,563	2,330,563	2,330,563	Additional Paid in Capital
(8,960,384)	(9,286,281)	(9,503,942)	Owner Distribution -
9,065,805	11,161,798	13,488,094	Retained Earnings
11,056,377	11,612,577	12,158,224	Net Income
13,492,362	15,818,657	18,472,939	Total Capital
24,751,511	25,373,325	26,941,877	Total Liabilities & Capital

Mega Valley Equine Hospital				
Discounted Cash Flow Valuation				
Initial Cash Flow*:	9,500,000			
Year Range:	1-5	6-10		
Growth Rate:	2%	2%		
Terminal Growth Rate:	1%		Discount Rate:	10.32%
Year	Flows	Growth	Value	
1	9,500,000	2%	8,611,313	
2	9,690,000	2%	7,961,873	
3	9,883,800	2%	7,361,413	
4	10,081,476	2%	6,806,238	
5	10,283,106	2%	6,292,932	
6	10,488,768	2%	5,818,338	
7	10,698,543	2%	5,379,537	
8	10,912,514	2%	4,973,828	
9	11,130,764	2%	4,598,717	
10	11,353,379	2%	4,251,896	
Terminal Year	11,466,913			
PV of Year 1-10 Cash Flows:				62,056,084
Terminal Value:				46,077,412
Total PV of Cash Flows - Total Value				108,133,497
Total Value X Marketability Discount	42.50%			62,176,761
EBITDA		4 Multiple	6 Multiple	Actual
Estimated 2017 EBITDA	12,985,737	51,942,947	77,914,420	4.79

Buyout Scenario						
Effective Tax Rate		28%				
Buyout Percentage		10%				
Note Terms						
Term		10				
Interest Rate		5.00%				
Loan Amount		6,217,676.06				
Payment		(\$805,217.49)				
Available Cash Flow		9,500,000				
New Partner Cash Flow		950,000				
Year	New Partner Cash Flow	Interest Expense	Net Taxable Income	Tax Expense	Principal Payment	Net Cash Flow
1	950,000	310,884	639,116	178,953	494,334	(34,170)
2	969,000	286,167	682,833	191,193	519,050	(27,411)
3	988,380	260,215	728,165	203,886	545,003	(20,724)
4	1,008,148	232,964	775,183	217,051	572,253	(14,121)
5	1,028,311	204,352	823,959	230,708	600,866	(7,615)
6	1,048,877	174,309	874,568	244,879	630,909	(1,220)
7	1,069,854	142,763	927,091	259,586	662,454	5,051
8	1,091,251	109,640	981,611	274,851	695,577	11,183
9	1,113,076	74,861	1,038,215	290,700	730,356	17,159
10	1,135,338	38,344	1,096,994	307,158	728,530	61,306
11	1,158,045	-	1,158,045	324,253	-	833,792
12	1,158,045	-	1,158,045	324,253	-	833,792
13	1,181,206	-	1,181,206	330,738	-	850,468
14	1,204,830	-	1,204,830	337,352	-	867,477
15	1,228,926	-	1,228,926	344,099	-	884,827

(10,562)

Service Marketing

Jorge L. Colón, DVM, MBA

To succeed as business owners, veterinarians must change their mental approach to daily work. Veterinarians must not only see themselves as veterinarians, but as being in the business of providing veterinary medical care; even when they sell medications to patients, they are doing so as an extension of the service provision. Author's address: PO Box 11631, Lexington, KY 40576; e-mail: jorgecolondvm@me.com. © 2017 AAEP.

1. Introduction

The concept of service marketing proposes that the success of any service provision should only be measured by the degree of customer satisfaction created. It also suggests that a market for veterinary services is made up by the people who are willing, able, and capable of purchasing the services; in other words, the people who want to buy veterinary services, have the financial means to buy the veterinary services, and have physical access to the veterinary services. Because different horse owners have different needs and wants, to develop a proper marketing strategy (Fig. 1) for the services that a veterinarian would like to offer, the veterinarian should divide this market or group of potential veterinary customers into different sets or segments of consumers; a process referred to as market segmentation. For example, while any horse owner willing to request veterinary care for their horses is part of the market for veterinary services, those looking for reproductive or lameness or race-track veterinary care make up different segments within the market.

After identifying the different segments of the market, the veterinarian can create a specific target group or target market for a particular veterinary service that the veterinarian would like to provide

by selecting the market segment in which to concentrate that particular veterinary activity. For example, if the veterinarian would like to offer soft-tissue tendon and ligament ultrasonography, the practitioner could create a target market based on the specific needs and wants of the owners of show horses within the practice area. Once the target market is created for a specific veterinary service, the veterinarian should develop a specific positioning strategy toward that target market. Your positioning strategy is what allows the consumer to perceive you as different relative to every other veterinarian that is attempting to provide the same veterinary service to that specific target market. For example, client education that goes beyond the education provided during clinical diagnosis is a key element of the positioning strategy of my own practice.

Creating a target market and a positioning strategy should be the first two steps of the practice's marketing strategy, the final one should be the creation of a market mix which is the creation of the service to be provided, the price for the service, the promotion of the service and the place of distribution for the service.^a This market mix should be specifically tailored to the selected target market (based on their known needs and wants) to reinforce the

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Fig. 1. Steps for creating a marketing strategy.

practice's positioning strategy that will make you be perceived by the consumer as different from everyone else for that specific veterinary service.

When a practice adds the tactical details regarding the when, who, and how of the marketing strategy implementation, the practice will have created its marketing plan for that specific veterinary service. Each veterinary service to be offered requires its own marketing plan (marketing strategy plus tactical details) to maximize the success of each particular veterinary service provision. Understand that the needs and wants of the show-horse owner wanting to breed their one mare with frozen semen are not the same needs and wants of the owner of a 20-Thoroughbred broodmare band. Although each of these reproductive scenarios presents a similar type of reproductive veterinary service, the difference in the target market requires different marketing strategies and marketing plans to maximize the degree of customer satisfaction created during the service provision. The combination of all marketing plans developed by the practice will make up the practice's marketing program.

Most service providers do not realize that there is a difference between finding clients that will utilize the services they provide, and identifying a target market for which the services to be provided will be tailored to meet the consumer's needs. The idea of service marketing not only requires the strategy to be designed based on the satisfaction of consumer wants, but should also adapt to changes in uncontrollable factors (i.e., political, legal, economic, and demographic changes) that ultimately change those specific consumer needs.

2. Service Experience

Truth is, there is really not that much difference in the skill level of good veterinarians. So where's the difference? Differentiation can be achieved through the consumer's perceived quality of the service experience; the service experience is the intangible process that can serve as the source of differentiation. When purchasing goods, the benefit perceived by the consumer is bundled and encapsulated within the good itself; when buying a pack of AAA batteries, a satisfactory experience might just

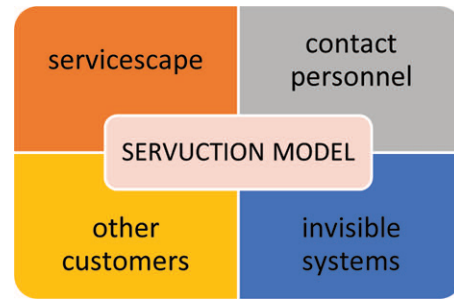


Fig. 2. Servuction Model framework.

be dependent on getting a trusted brand for a reasonable price. Services, in contrast, deliver the bundle of benefits through the experience that is created for the consumer; getting a good-tasting meal at a reasonable price in a restaurant might not be a satisfactory dining experience if it was marred by bad service, obnoxious patrons, and filthy restroom facilities. So while the marketing strategy discussed is essential in developing the service, there are manageable factors that can impact and influence the experience.

3. Servuction Model

The Servuction Model (Fig. 2) provides a framework for understanding the consumer experience and basically relies on the fact that the quality of the service will depend on the perceived experience, not just on the result of the service. Under this model there are four factors that influence the experience:

1. **Servicescape:** the servicescape are the non-living aspects that provide tangible clues about the service to be received. Is the clinic neat and tidy? Are the decorations inviting? Was the entranceway clean of snow in the winter? All these things give the client a clue about the service to be received and make a difference in the perception of quality by the consumer.
2. **Contact personnel:** what are the interpersonal skills presented by the service provider and assistants? Their appearance? The contact personnel are the public face of the practice; they are the practice's representation in the implementation of the marketing strategy.
3. **Other customers:** other customers can impact the service experience through their ability to disrupt the experience or through their positive or negative comments about their own experience. You will have a 100% chance of someone chiming in with their opinion if you discuss a case with a horse owner in the middle of the riding barn on a busy Saturday afternoon. Although a veterinarian can control the message provided by the servicescape and the contact personnel,

the potentially unwanted influence coming from other customers will not be controllable unless you take preemptive action. If possible, the veterinarian should make an effort to isolate the service experience from this outside influence to better control the delivery.

4. Invisible organization and systems: there are behind-the-scenes things that the customer never sees that impact the customer experience. Was your appointment book kept updated or did you just forget that the farm call was scheduled for noon and not 2:00 pm? Was a payment not properly recorded and the client got a past-due bill for a service already paid? Systems that are invisible to the customer can easily and rapidly alter the perceived experience.

The reasons why controlling the service experience is so essential are directly interrelated to the characteristics of service that differentiate it from the transfer of a good:

1. Intangible: unlike a good, a service is an intangible that cannot be stored; the customer cannot touch it or inspect it before consumption. For this reason, the customer does not own the service after provision, they just experience it. The veterinarian will not necessarily have a happy horse owner after saving the animal's life if the veterinarian was rude and disrespectful during the emergency.
2. Inseparability: the service provider and the customer are both directly involved in the service production process. The customer's presence is a factor that somewhat inhibits mass production of the service as both parties must be present simultaneously. In addition, the length of service delivery is dictated by the customer's presence and needs; explaining and communicating are as important to the experience as the veterinary service itself.
3. Heterogeneity: standardization of the service provision is difficult to achieve and control because there is an inherent variability in the people factor related to the production of the service. A customer will have a zone of tolerance based on a range between expected and adequate service. As long as the delivered service falls within this range, a variation in quality will still be acceptable.
4. Perishability: a service is consumed at the time of production and therefore production and consumption cannot be separated by time and space. This creates a problem related to supply and demand as the service provider will find a time-related ceiling in the physical ability to fulfill rising demand. The inability to inventory the ser-

vice means that its quality cannot be measured prior to consumption, the measuring occurs during and after the service experience.

Overall, there are strategies that can be implemented to address these service characteristics like tactics to smooth out demand (i.e., pricing strategies on dental services during the slow season) or to manage the supply (i.e., practice expansion or part-time employees). As previously mentioned, when it comes to service provision, the satisfaction is not just with the outcome, but also with the process.

4. Customer Satisfaction

The customer's satisfaction is based on the experience with the outcome and the process. Attention to the process is the way to achieve that desired differentiation; therefore the veterinarian has to develop behaviors that will improve the customer's satisfaction with the process. Among the many different theories of how to explain customer satisfaction, the expectancy disconfirmation perspective presents a simple way for a veterinarian to visualize how to positively affect the experience. Although expectations are defined by what the customer thinks he is going to get from the service experience, perceptions are what the customer believes he got from the service experience. For the customer, perceptions define reality. The expectancy disconfirmation perspective suggests that customer satisfaction is the result of perceptions meeting or exceeding expectations. The practitioner needs to understand what the client's expectations are, then figure out ways to deliver a service experience that will equal or exceed those expectations.

So where do the customer's expectations come from? There are explicit service promises based on advertising, communications, and contracts. There are also implicit service promises based on things such as price and servicescape. Expectations are also affected by promises created by word of mouth and by past experiences. Put together, these promises impact the predicted level of service expected by the customer. If this expectation fulfills the needs of the customer's desired service, then the veterinarian will have the opportunity to provide the service and hopefully do his part to meet or exceed those expectations.

The reasons to achieve customer satisfaction should be obvious: unhappy customers do not return and spread negative word of mouth; satisfied customers bring repeated and more frequent business together with positive word of mouth. In addition, satisfied customers are not only less likely to be lost to competition, but they will also be more insulated from price competition; meaning that not only will they not want to leave you, but they are less likely to be tempted to leave because of lower prices.

5. Dissatisfied Customer

It would be impossible to meet or exceed every client's expectations. Although counterintuitive, the veterinarian should encourage all clients to complain about any unsatisfactory perception of experience. A complaint is an opportunity for recovery. Although dissatisfied noncomplainers just walk away, marketing studies have shown that customers who have had their complaints heard and resolved are more likely to provide repeat business, together with positive word of mouth about the positive resolution of a dissatisfaction. In fact, a complainer who has had his issue resolved might become a better client and practice promoter than the client who never had an issue with the service in the first place. The complaint also provides clues as to what part of the expectation creating promises needs to be addressed. You cannot control someone creating a superhero image of you to a horse-owning friend that leads to unrealistic expectations of the service they, in turn, may receive; but you can control making an explicit service promise if, for example, a previous experience has brought about the realization that the specific promise cannot be fulfilled.

Key to the ability to resolve a customer's complaint is the development of a service recovery program that will actually allow for differentiation in the face of a dissatisfied customer. The service recovery program should create an opportunity to satisfy the customer's needs and wants within the period of dissatisfaction. The goal is to avoid client defection and the loss of the customer's lifetime value to the practice. The program should encourage complaint feedback and provide a framework for

the process of response and resolution. Though not all negative disconfirmation scenarios will be resolved effectively, positive resolution of some of them will lead to positive differentiation because the service process during recovery from a dissatisfaction will always be part of the customer satisfaction equation.

6. Conclusion

Veterinarians have not been trained to be business people. In order for veterinary businesses to thrive, veterinarians must change their mindset and realize that veterinary medicine is not just about the outcome of a procedure, but also about the experience perceived by the client during the process. If you become an astute clinician through training and experience, you will satisfactorily compete with other equally good veterinarians. But if you develop service delivery skills that will enhance the client's perceived experience during the service provision, you will differentiate yourself from the crowd and create satisfied clients that will never want to leave you.

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.

Footnote

^aIn general marketing, the marketing mix is referred to as the four P's: product, place, price, and promotion.

Insights from an On-Line Survey of 8069 Horse Owners Regarding Equine Veterinary Care

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Online survey tools can provide equine practitioners valuable information about horse owners that can be used to improve the quality of veterinary care provided. Authors' addresses: PO Box 4018, Sunland, CA 91041 (Ramey); University of Toronto, 210 Wychwood Ave #1, Toronto, ON M6C 2T3, Canada (Ordal); and University of California–Los Angeles, Fielding School of Public Health, 640 Charles E Young Drive South, Los Angeles, CA 90024 (Lee); e-mail: ponydoc@pacbell.net. © 2017 AAEP.

1. Introduction

Anonymous feedback surveys provide valuable information for businesses. They can assist in assessing employee satisfaction, helping to understand the dynamics of the workplace, and in assessing the performance and productivity of the company.

In human medicine, patient satisfaction surveys are commonly performed to improve the care and experience of patients. Although disconnect between patient satisfaction and health outcomes has been reported,¹ medical patient satisfaction surveys can nevertheless provide useful insights into different aspects of a health care business, including personnel, facilities, and procedures, and can thus identify areas that need improvement. Even the act of soliciting feedback can help create an image of trustworthiness.

Although individual veterinary practices may collect satisfaction surveys, the extent and manner in which such surveys are conducted is largely unknown. Online survey tools are widely available and easy to use and they may offer a potential method to help veterinarians gain a better understanding of their clients. This survey of 8069 horse

owners was conducted using one such online survey software and questionnaire tool. The objective of this survey was to obtain information about veterinary clients and certain preferences relevant to clinical equine veterinary practice.

2. Materials and Methods

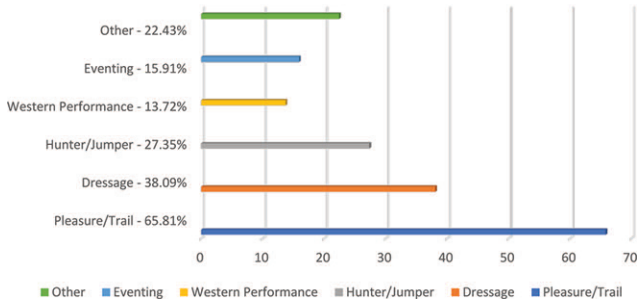
A survey with 23 questions about veterinary care provided to horse owners was developed and posted to SurveyMonkey, an online survey site.^a Two questions, pertaining to equestrian activities, and reasons that horses were examined (Questions 1 and 5) allowed more than one answer. Prior to the survey the questions were reviewed by a biostatistician and two experienced equine practitioners, all at arm's length, to assess wording, relevance, and interest to horse owners.

The survey was posted on December 19, 2016, and closed on March 6, 2017, having been promoted on the lead author's Facebook blog page and shared in a snowball sampling fashion. Results from the final tally of 8069 respondents were analyzed with simple descriptive statistics. Some questions were skipped by respondents; the number of responses is indicated with each question.

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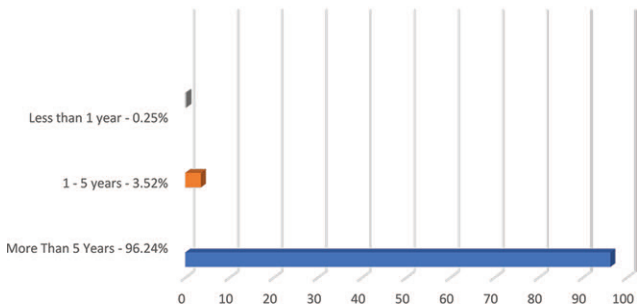
3. Results (Ordered by Survey Question)

Question One - In Which Type of Equine Activity Do You Participate? - 8059 Respondents

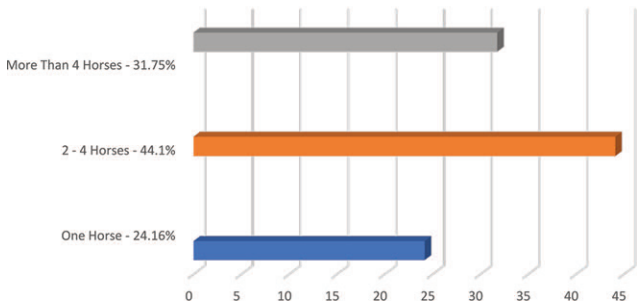


Those identifying as “Other” were 22.43% of respondents and included the use of horses as companions, and for polo, clicker training, saddle seat, fox hunting, pleasure driving, equine-assisted therapy, and reining. “Other” had considerable overlap with other disciplines; for example, people may have identified themselves as barrel riders rather than participants in Western Performance Horse events.

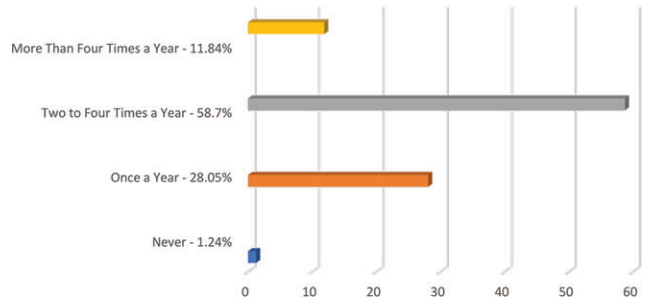
Question Two - How Long Have You Owned or Ridden Horses? - 8050 Respondents



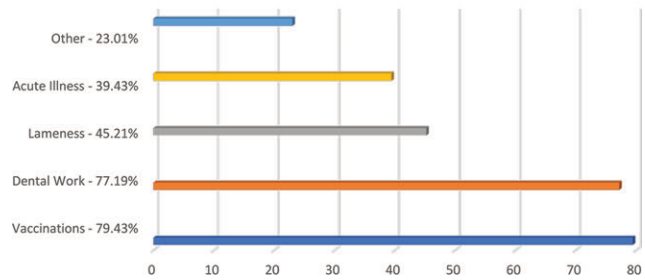
Question Three - How Many Horses Do You Currently Own or Work With? - 8048 Respondents



Question Four - On Average, How Often Do You See a Veterinarian About Each Horse? - 8051 Respondents

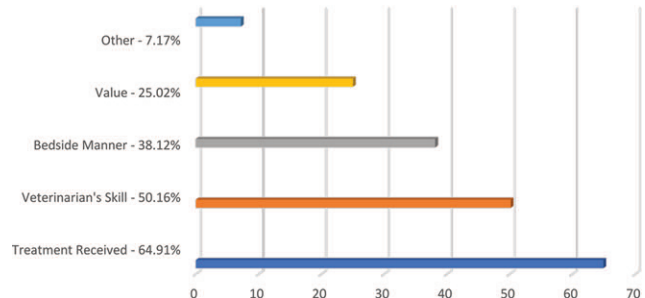


Question Five - For Which of the Following Reason(s) Have You Had Your Horse(s) Examined in the Past Year - 8052 Respondents



Acute illness included colic, respiratory disease, and skin problems. “Other” reasons to see veterinarians came in at 23.01% of respondents, and included examinations fulfilling requirements for interstate transport, choke, wound management, application of various “alternative” therapies, and breeding.

Question Six - What Part of the Veterinary Visit Was Most Satisfying to You? - 8028 Respondents

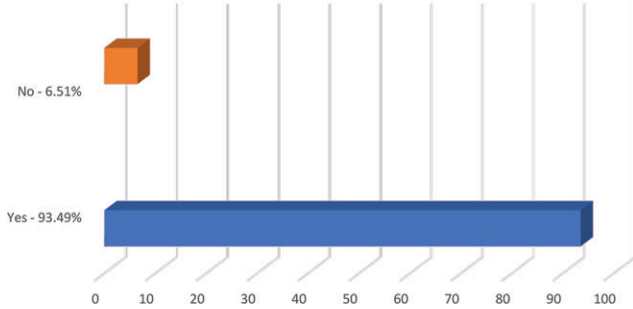


“Other” reasons for satisfaction were selected as 7.17% of responses, and included peace of mind and reassurance. A small number of individual respondents expressed dissatisfaction with their

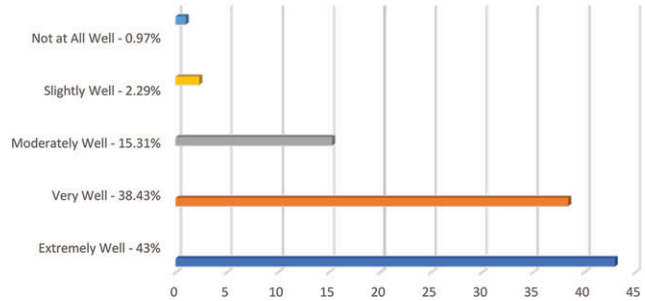
veterinarian(s); this was not tabulated as a percentage.

“Other” ways respondents found their veterinarian (16.85%) included limited choices, and referral by barn owners or trainers.

Question Seven - Will You Use the Same Veterinarian the Next Time Your Horse Needs Care? - 8046 Respondents

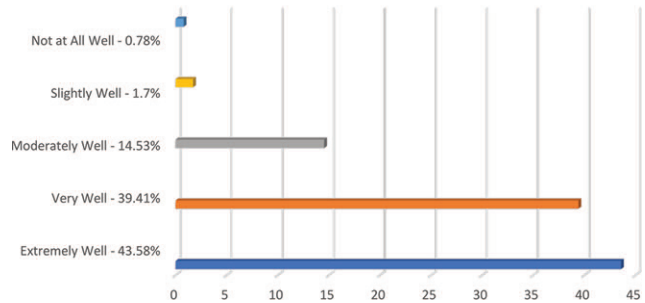


Question Ten - How Well Does Your Veterinarian Listen To You? - 8045 Respondents

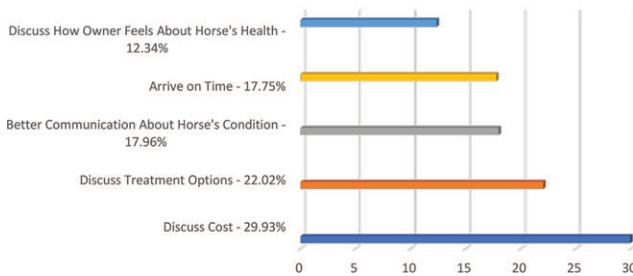


Various reasons were given for not using the same veterinarian again, including an inability to have service from the same veterinarian (in multi-veterinarian practices), poor communication skills, failure to come up with a diagnosis, failure to attend to emergencies, cost, and billing problems.

Question Eleven - How Well Does Your Veterinarian Answer Your Questions? - 8051 Respondents

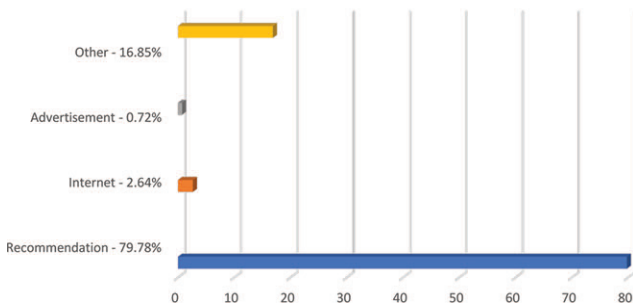


Question Eight - If You Could Improve One Aspect of Your Veterinarian's Services, What Would it Be? - 7003 Respondents

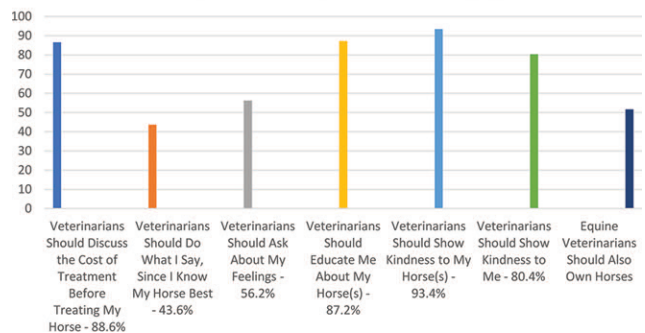


Questions 12 to 18 were posed on a star scale format, with 1 star being the lowest level of agreement and 5 stars being the highest. These were statements meant to assess what was important to the respondents, as opposed to an evaluation of the service they received.

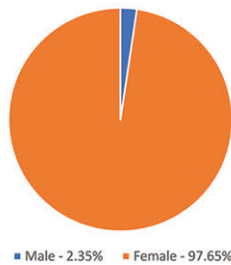
Question Nine - How Did You Find Your Veterinarian? - 8018 Respondents



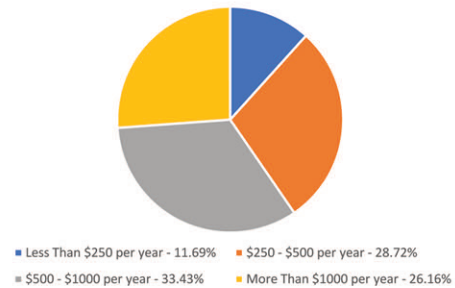
What Was Important to Respondents - Strong Agreement



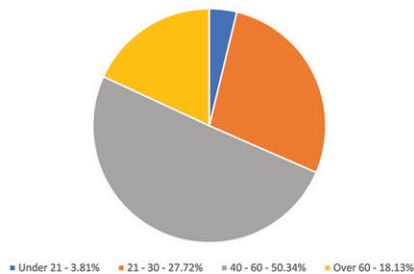
Question Nineteen - Are You Male or Female?
8035 Respondents



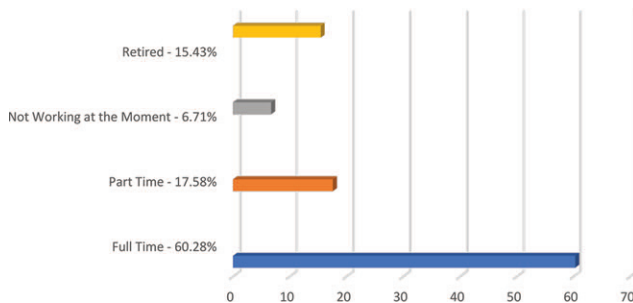
Question Twenty-Three - On Average, How Much Money Do You Spend On Veterinary Care for Your Horse Per Year?
8043 Respondents



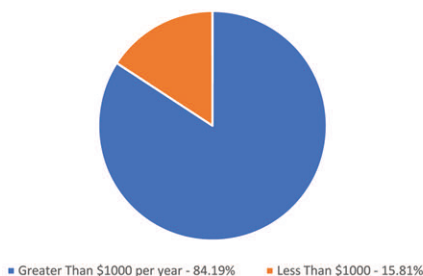
Question Twenty - How Old Are You? - 8053 Respondents



Question 21 - What Best Describes Your Work Status? 8049 Respondents



Question Twenty-Two - On Average, How Much Money Do you Spend on Your Horse Per Year (Estimate)? - 8033 Respondents



4. Discussion

During the past 10 to 15 years, the use of online and mobile methods for survey research has allowed do-it-yourself researchers to design, conduct, and analyze surveys for a relatively small cost. Surveys are a powerful research tool, as long as their limitations are understood. Online surveys in particular can reach very wide audiences, exploiting the “viral” phenomenon as posts are shared via social media. Respondents input their own data, and it is automatically stored electronically. Analysis thus becomes easier and is available immediately. Such surveys are convenient for respondents, who can answer questions on their own schedule, and at their own pace. Surveys can be designed with varying degrees of complexity. In an online format, respondents may be more willing to share information since that information is not being disclosed directly to another person. The anonymity provided by the online platform also restricts the influence of interviewers on responses.

Online surveying has some disadvantages. For example, certain populations may be less likely to have Internet access and may not be able to respond to online questionnaires. It is also harder to draw probability samples based on email addresses or Web site visitations. Although interviewers can influence responses, the lack of a trained interviewer to clarify and probe can possibly lead to less reliable data. It is not possible to verify identity in any way, and there is no guarantee that the responses will be equivalent to those that would have resulted from a paper-based survey. The resulting sample, as noted in the responses, was overwhelmingly female adults (over 21 years of age), who owned horses for more than 5 years. The majority were pleasure/trail riders and owned at least 2 horses. As a result, the findings from this survey would reflect that population.

Online surveys are highly prone to sample bias, given that they are often shared among people with similar interests and attitudes; this, however, may also work in the researchers’ favor if they are interested in the opinions of a certain homogenous group.

Surveys that are particularly long or require a great deal of free text answers are especially vulnerable to sample bias, given that they naturally select for respondents with strong opinions on the survey subject. For these reasons, this survey was designed to be fairly short, with relatively simple answer choices. Recall bias, that is, systematic error due to differences in accuracy or completeness of recall to memory of past events or experiences is another potential bias,² as is the “halo effect,” where the overall impression of a person, company, brand, or product can influence the observer’s feelings and thoughts about that entity.³

Ethically, one of the key advantages to using online methodology is that given that IP numbers are typically not collected, there is no way of tracing respondents. There is no need to use email addresses unless follow-up questions are part of the survey design, and there is less likelihood of invading privacy.⁴ Respondents can be advised of the uses that will be made of the data (including publication and other forms of dissemination), which is central to informed consent. This can be presented and explained on the first page of the survey prior to answering questions, making use of the “implied consent” model wherein completion and submission of the survey implies consent to use the data for research purposes.

Relatively few marketing/satisfaction surveys of horse owners seem to have been published. In 2012, the American Association of Equine Practitioners conducted a survey of 6148 horse owners and trainers, in response to concerns about decreasing frequency of use of equine veterinarians.⁵ American Horse Publications has conducted 3 such surveys, with the most recent survey of 10,662 horse owners being completed in 2015.⁶

This survey identifies some interesting areas of consideration for equine veterinarians, especially for those with practices covering the main demographic groups identified in this survey (primarily female, employed, 40 to 60 years of age, with one or more pleasure or performance horse competing in various disciplines). Many of these areas have been highlighted in other surveys. For example:

- Equine veterinarians who do not practice equine dental care might consider adding this expertise to their practice, given that 77.19% of respondents saw their veterinarians for equine dental work.
- Clients seem to be more interested that their horse be treated with kindness, as opposed to kindness shown by the veterinarian to themselves.
- Clients value discussing the cost of treatment, as well as treatment options, prior to treatment being performed on their horses.
- Most veterinarians seem to communicate

fairly well, but communication is important to most horse owners.⁵⁻⁷

- Clients appreciate being educated about their horses by their veterinarians.
- A majority of clients want the veterinarian to do what they think is best, even if they think they know what is best for their horses.
- A significant number of clients (43.6%) feel that they know what is best for their horse, and want their veterinarian to act accordingly.
- The treatment received by the horse seems to be far more important than the value for treatment received.
- Recommendations from friends, family, barn owners, and trainers are a far more important source of business than is advertising or Internet presence.

The potential exists for online surveying to be a powerful tool in assessment of a variety of areas of equine veterinary medicine, including after-market product assessment, customer satisfaction, and identifying sources of information from which horse owners are educated about their horses (to name a few). Equine veterinarians may want to make use of such surveys to improve their practice and client satisfaction.

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.

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^aSurveyMonkey, 3050 S. Delaware Street, San Mateo, CA 94403. www.surveymonkey.com.

Diagnosis and Management of Sinus Conditions in the Equine Patient

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1. Introduction

Paranasal sinus disease is usually the consequence of obstruction of the drainage ostia as a consequence of inflammatory processes initiated by primary bacterial infections, bacterial or fungal infection secondary to other disease processes such as dental disease, and space-occupying expansile lesions and trauma.¹⁻⁵ The equine paranasal sinuses are a complex anatomical area with multiple structures of different densities, which have made accurate diagnosis of certain conditions challenging.⁶⁻⁷ Historically radiography and nasal endoscopy have been used as primary diagnostic tools to evaluate this area. However, due to anatomic complexity, superimposition of osseous, soft tissue, and dental structures, accurate diagnosis and thus effective treatment can be challenging.⁶ This in part might be responsible for the relatively high percentage of cases, as high as 47%, that historically have been reported to develop complications following surgical treatment.²

2. Imaging of the Paranasal Sinuses

Although an accurate diagnosis can be made using conventional imaging modalities such as radiography and nasal endoscopy, in certain cases these fail to give the clinician an accurate idea regarding the

extent of the lesion and the structures affected. Other imaging modalities, such as sinuscopy and nuclear scintigraphy can provide useful information although not without limitations. Perkins and colleagues reported on their experience visualizing the ventral conchal and rostral maxillary sinus using conchofrontal sinuscopy along with fenestration of the ventral conchal bulla.^{8,9} In that report they found sinuscopy to be particularly useful in cases of primary sinusitis from both a diagnostic (82%) and therapeutic (77%) standpoint; however, this technique did not demonstrate particularly useful in cases of secondary sinusitis such as tooth-root infections.⁹ Nuclear scintigraphy has been shown to be an extremely sensitive diagnostic imaging technique for identifying areas of bony inflammation and remodeling.¹⁰ In the equine head it can be used to identify and distinguish primary sinusitis from secondary sinusitis due to dental disease or neoplasia. Although ⁹⁹Tc-methyl disphosphonate (MDP) is typically used, ^{99m}Tc-hexamethylpropyleneamine oxime (HMPAO)-labelled white cells can be used successfully to identify tooth-root abscess. Scintigraphy has the disadvantages of lacking a good three-dimensional representation of the sinuses and the potential for both false negatives and positives due to artifacts. In particular, when dealing with cases

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of dental disease scintigraphy can fail to discern with certainty the specific tooth root affected. However, when combined with radiography and in some instances sinuscopy, scintigraphy can have a high sensitivity and specificity.

Computed tomography (CT; and to a lesser extent magnetic resonance imaging [MRI]) is considered by many to be the current gold standard for a complete evaluation of the sinus cavities in equine patients.^{6,7,11-14} Major advantages include the lack of superimposition of structures or summation of bony densities seen with radiographs. In addition, there is potential for the characterization of fluid densities, good visualization of the individual tooth roots, and the condition of the various communications between the different sinus cavities.¹¹ There are a number of recent publications in the past 2-3 years that describe the CT (and MRI) characteristics of conditions commonly affecting the paranasal sinus region that will be discussed in this presentation.^{6,11-13} In addition, with the increased prevalence of multi-slice helical CT scanners and sophisticated processing software, image reconstruction, and manipulation offers the surgeon a unique perspective of the affected area prior to surgery.

3. Anatomy of the Paranasal Sinuses

Six paired sinuses make up this region: the frontal, dorsal conchal, ventral conchal, rostral maxillary, caudal maxillary, and sphenopalatine (ethmoidal) sinuses.^{1,2}

The frontal sinus extends from the rostral aspect of the calvarium up to half the distance between the infraorbital foramen and the orbit, and is contiguous rostrally with the dorsal conchal sinus (thus forming the conchofrontal sinus as it is also known). The ventral conchal sinus lies axially, slightly dorsal to the rostral maxillary sinus with whom it communicates. The boundaries of the maxillary sinuses are the following: the dorsal limit is represented by a line drawn from the infraorbital foramen caudally parallel to the facial crest in line with the medial canthus of the eye; the rostral limit is represented by a vertical line from the facial crest to the infraorbital foramen; the caudal limit is slightly rostral to the root of the orbital process of the zygomatic bone; the ventral limit is at the level of the teeth roots. The maxillary sinuses are divided into rostral and caudal compartments by a complete oblique bony septum that begins approximately 5 cm caudal to the rostral extent of the facial crest.

The rostral maxillary sinus communicates with the ventral conchal sinus and the caudal maxillary sinus communicates with the frontal sinus via the frontomaxillary aperture. Drainage into the nasal cavity occurs via a common nasomaxillary aperture that enters the middle nasal meatus at the level of the medial canthus of the eye. Any inflammation may occlude either duct or common aperture, thus perpetuating the disease process or making lavage or drainage difficult.

4. Bacterial Sinusitis

Bacterial sinusitis can be primary or secondary in nature; secondary causes include dental disease, trauma, paranasal sinus cysts, granulomatous lesions, and neoplastic processes such as squamous cell carcinoma.^{3-5,9,15} Clinical signs include unilateral nasal discharge, dullness of the sinus on percussion, and rarely, facial deformity. The most common sinuses affected in cases of primary sinusitis are the rostral and caudal maxillary sinuses as well as the ventral conchal sinus. This is a consequence of all sinuses draining through the two maxillary sinuses, and the susceptibility of the nasomaxillary opening to mucosal inflammation and obstruction. Upper respiratory tract infections such as influenza and equine herpes virus-4 can also create enough mucosal inflammation to obstruct drainage from the sinuses while concurrently increasing mucous production by the sinus mucosa. Once that happens, a secondary bacterial infection can ensue resulting in sinus empyema. These infections can be self limiting; however, if inspissated pus accumulates and drainage is not efficient enough, a chronic primary sinusitis will develop.

In chronic sinusitis, purulent material commonly collects in the ventral conchal and rostral maxillary sinuses due to their poor drainage. Once this pus becomes inspissated, removal by normal physiologic mechanisms is practically impossible. In addition, due to the axial location of the ventral conchal sinus, inspissated pus becomes trapped on the floor of this sinus and even regular lavage has been proven to be an ineffective method to clear it. If CT is not available, the use of combined imaging modalities such as radiography and in particular sinuscopy through a fenestration of the ventral conchal bulla as described by Perkins and colleagues cannot only be diagnostic but potentially therapeutic to remove inspissated material.⁹

Treatment of bacterial sinusitis will depend on the underlying etiology. Although cases of acute primary sinusitis will usually resolve spontaneously, the use of antibiotics and sinus lavage can help resolve some cases faster. Lavage of the sinus is also a critical aspect of effective management of sinusitis. However, in order for lavage to be effective, a patent nasomaxillary opening is needed to ensure drainage into the nasal passage; if the nasomaxillary opening is not patent, it can be potentially dilated¹⁶ or an opening in the rostral aspect of the conchal sinus can be created. Lavage should be performed once or twice a day with 1-3 L sterile saline with or without the use of dilute betadine or chlorhexadine. In cases of secondary sinusitis where an abscess, inspissated exudates, or infected tooth root is the primary cause of the condition, debridement of the affected area via a frontal or maxillary sinusotomy (either standing or under general anesthesia) will be necessary as the use of antibiotics alone will be ineffective.^{1,2,5,15,17} Prognosis for cases of primary sinusitis is typically

excellent; cases of secondary sinusitis will have a variable prognosis based on the underlying cause.

5. Sinusitis Secondary to Dental Pathology

The most common of dental pathology affecting the paranasal sinus region is tooth root abscessation involving the third through sixth maxillary cheek teeth, which reside within the rostral and caudal maxillary sinuses.^{1,2} In these cases, nasal discharge is typically copious and malodorous due to the anaerobic bacterial component that these abscesses regularly will have. In these cases radiographic identification of the precise affected tooth root can be challenging and other imaging modalities such as nuclear scintigraphy, but in particular CT can be critical in coming up with an accurate diagnosis and location of the affected tooth, including the presence of small fistulas that communicate with the oral cavity. These cases will only transiently benefit from antibiotic administration and sinus lavage; removal of the affected tooth root and debridement/removal of the abscess is necessary for complete resolution. It is this author's opinion as well as others that these cases benefit greatly from performing a CT study preoperatively to accurately identify and develop an effective surgical plan. Subjectively this has resulted in a reduction in post-operative complications and recurrence, which in the long run is more cost effective.

6. Paranasal Sinus Cyst

Cysts within the paranasal sinuses are not an uncommon cause of sinusitis, typically affecting the frontal or maxillary sinuses.² These cysts are mucoid filled and of unknown etiology. As they enlarge they can cause occlusion of the nasomaxillary opening precluding drainage and resulting in fluid accumulation within the sinus that may obscure the radiographic appearance of any cystic structures. Cysts can also create variable amounts of mucosal inflammation and can create significant facial swelling. Because of the aforementioned occlusion of the nasomaxillary opening, these cases will typically show little to no nasal discharge. When present, this discharge is not quite as purulent as with other conditions affecting the sinus and will not be malodorous. In some cases, completing nasal endoscopy is not possible due to obstruction of the affected nasal passage from mucosal swelling and turbinate distortion. In cases with facial swelling, aspiration of the cyst can be performed with a 14-gauge needle as the deformed bone is typically thin; aspiration will usually reveal a white or clear yellow fluid. A full radiographic series including lateral, oblique and dorso ventral projections will show a homogenous, rounded, soft-tissue-density mass with occasionally a partially mineralized capsule. In addition, fluid lines are commonly seen due to the secondary empyema that these cysts create. On occasion it can be difficult to identify or differentiate a paranasal sinus cyst from other pathologic conditions due to similar

soft-tissue-density characteristics or because of the presence of abundant empyema. In these instances, the use of CT can be tremendously beneficial to characterize the lesion type as well as define its exact location, which will dictate treatment and surgical approach.

The ideal course of treatment for paranasal sinus cysts is surgical removal via the appropriate sinus flap. To reduce the chance of recurrence, as much of the capsule and lining of the cyst should be removed. Prognosis in these cases is typically excellent with adequate management.

7. Progressive Ethmoid Hematomas

Progressive ethmoid hematomas (PEHs) are defined as a slowly expansive hematoma that develops under the respiratory mucosa in the area of the ethmoid labyrinth.¹ In these cases the mucosa stretches to accommodate the expanding hematoma. Although most PEHs occur in the caudal nasal passage, they can also occur within the paranasal sinuses. Clinical signs include serosanguineous to sanguineous discharge, respiratory stridor, or exercise intolerance for those that expand sufficiently within the nasal passage and rarely facial distortion (when present within the maxillary sinuses). Nasal endoscopy will reveal an enlarged, discolored, and necrotic mass in the ethmoidal conchae. When performing endoscopy in these cases, it is important to examine both nasal passages given that bilateral disease can exist without bilateral clinical signs and this can have a significant effect on prognosis and recurrence. Radiographs can also be effective with dorsoventral and oblique projections typically yielding the best results. However, small PEHs can be missed based on their location within the sinuses. A CT scan of these cases when a PEH within the sinuses is suspected can be invaluable in ruling in or out this condition. Treatment of PEH within the nasal passage can be performed with sequential intralesional 10% buffered formalin injection treatments spaced once every 2–3 weeks for an average of three to seven treatments. Alternatively, PEHs within the nasal passages can be ablated with the use of sequential Nd:YAG laser treatments in non-contact mode. In cases of PEHs within the paranasal sinuses, removal via sinusotomy with or without the use of a laser is recommended. Prognosis is typically guarded as recurrence can be high, especially in bilateral cases.

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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Overground and Resting Endoscopic Diagnoses

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1. Introduction

Resting endoscopic examinations of the nasopharynx and larynx in horses presented for investigation of abnormal respiratory noise and/or poor performance during exercise are performed for two principal reasons: first to identify gross structural abnormalities that are apparent at rest, and second to use the appearance and function of the larynx or nasopharynx at rest as predictors for their function during exercise.

Endoscopic examination of horses running on the treadmill was the sole method for evaluating the upper respiratory tract (URT) at exercise until the late 2000s when mobile over-ground endoscopy units began to be developed. During the last 7–8 years there has been a considerable increase in the availability of these remote over-ground endoscopic systems. This has made exercising endoscopy accessible to a wider variety of operators and clients than previously, because treadmill examination is restricted to a handful of veterinary schools and larger private practices.

2. Resting Endoscopic Examination

Laryngeal Function at Rest

Resting laryngeal function grading systems are used to make an informed prediction of the likelihood of dynamic laryngeal collapse occurring during exercise. Several grading systems for laryngeal func-

tion at rest have previously been described in the literature. In 2003 a consensus system of endoscopic laryngeal grading (the Havemeyer system) was developed by an international panel of specialists.¹ The Havemeyer laryngeal grading system (Table 1) is loosely based upon the 4-grade system originally described by Hackett et al² but has additional sub-grades in grades 2 and 3. The Havemeyer system has become widely utilized, with several large clinics in the United States, United Kingdom, Australia, and other countries now using it routinely. This grading system has been correlated with severity of pathological changes in laryngeal muscles³ and its interobserver, intra-observer, and intrahorse repeatability has been investigated in horses at rest and at exercise.^{4,5} In addition, the Havemeyer resting subgrades have been correlated with exercising endoscopic findings.^{6,7}

Generally speaking, horses with grade 1, 2.1, and 2.2 laryngeal function are deemed to be within normal limits and have a fairly low prevalence (3–7%^{6,8,9}) of dynamic laryngeal collapse (vocal fold or arytenoid cartilage collapse). At the other end of the scale, horses with grade 4 laryngeal function at rest ubiquitously experience complete collapse (grade C) of the left arytenoid and often bilateral vocal fold collapse. Horses with Havemeyer grade 3 laryngeal function, often referred to as the “equivocal” grade, present the most challenges to clini-

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Table 1. Havemeyer Grading System for Laryngeal Function at Rest and Exercise

Resting Grade	Description	Sub-Grade
1	All arytenoid cartilage movements are synchronous and symmetrical and full arytenoid cartilage abduction can be achieved and maintained.	
2	Arytenoid cartilage movements are asynchronous and/or larynx is asymmetric at times but full arytenoid cartilage abduction can be achieved and maintained.	2.1: Transient asynchrony, flutter, or delayed movements are seen. 2.2: There is asymmetry of the rima glottidis much of the time due to reduced mobility of the affected arytenoid and vocal fold but there are occasions, typically after swallowing or nasal occlusion when full symmetrical abduction is achieved and maintained.
3	Arytenoid cartilage movements are asynchronous and/or asymmetric. Full arytenoid cartilage abduction cannot be achieved and maintained.	3.1: There is asymmetry of the rima glottidis much of the time due to reduced mobility of the arytenoid and vocal fold but there are occasions, typically after swallowing or nasal occlusion when full symmetrical abduction is achieved but not maintained. 3.2: Obvious arytenoid abductor deficit and arytenoid asymmetry. Full abduction is never achieved. 3.3: Marked but not total arytenoid abductor deficit and asymmetry with little arytenoid movement. Full abduction is never achieved.
4	Complete immobility of the arytenoid cartilage and vocal fold.	
Exercising grade		
A	Full abduction of the arytenoid cartilages during inspiration.	
B	Partial abduction of the affected arytenoid cartilages (between full abduction and the resting position).	
C	Abduction less than resting position including collapse into the contralateral half of the rima glottidis during inspiration.	

cians, given that they can exhibit a wide range of laryngeal appearances during exercise. Choosing an appropriate surgery for these horses should be reliant on the results of exercising endoscopy. Hackett et al² and Hammer et al¹⁰ found, respectively, that 1/6 (16%) and 25 of 26 horses (96%) with resting grade 3 laryngeal function experienced dynamic laryngeal collapse during treadmill endoscopy. A larger study by Martin et al⁸ reported that 29 of 36 horses (80%) with resting grade 3 laryngeal function developed arytenoid collapse during exercise. The largest published study to date⁹ used a different endoscopic grading system at rest, but found that 57 of 141 horses (40%) with resting laryngeal function grades approximately equivalent to Havemeyer grade 3 function experienced dynamic laryngeal collapse during high speed treadmill examination (HSTE). In the study by Barakzai and Dixon,⁶ 66% of the 51 horses with resting grade 3 laryngeal function exhibited either partial or complete arytenoid collapse during exercise. These authors also reported that the resting subgrades of grade 3 were significantly correlated with an increasing likelihood of arytenoid collapse occurring during exercise and with the severity of the collapse that occurred. Vocal fold collapse is reported to occur with increasing

frequency as the resting laryngeal function grade increased from 1 to 4, and with increasing subgrades of grade 3.⁶

Palatal Function at Rest

Exercising endoscopy is required to make a definitive diagnosis of palatal dysfunction; however, in the clinical situation, access to such facilities and equipment may be limited, and it can be challenging to persuade some owners and trainers of the value of such examinations. There is contradictory evidence regarding the usefulness of resting endoscopic findings in predicting the development of dorsal displacement of the soft palate (DDSP) at exercise.^{9,11,12} The two largest studies to date have reported marked differences in the percentage of horses definitively diagnosed with DDSP that exhibited either persistent or transient DDSP during their resting endoscopic examination: 51 and 11%, respectively, by Parente et al¹² and Lane et al.⁹ Lane et al⁹ and Barakzai and Dixon⁶ both found that the presence of spontaneous DDSP during resting endoscopy was a highly specific (95%) but extremely insensitive (15–26%) test for the gold standard of DDSP occurring during HSTE. Therefore, use of resting endoscopy alone as a diagnostic test for ex-

exercising DDSP within a similar population of horses would result in few false-positive tests, but a very large number of false negatives. When considering the implications of using this test in an individual horse, the positive and negative predictive value (PPV and NPV) of the test should be examined, rather than sensitivity and specificity. If an individual horse making abnormal respiratory noise at exercise exhibits DDSP on a resting endoscopic examination, this test would be correct in predicting DDSP at exercise in approximately half of cases (PPV = 0.57).⁶ Conversely, the absence of DDSP at rest is a slightly more accurate predictor that an individual horse will not experience DDSP during exercise (NPV = 0.83).⁶

Persistent DDSP is a different syndrome to intermittent idiopathic DDSP at exercise, and is obvious in horses at rest, given that the palate remains displaced almost all the time, including after swallowing.¹³ When persistent DDSP is seen on a resting scope, further manipulations should be performed to examine the epiglottic cartilage and sub-epiglottic area, usually possible by topically anesthetizing the area and using broncho-oesophageal forceps to manipulate the palate and epiglottis, or by passing the scope *per os*.

Other Resting Abnormalities

Some abnormalities of the URT are evident immediately using resting endoscopy and in most of these cases, exercising endoscopy is not required to make a diagnosis and treatment plan. These include arytenoid chondritis, laryngeal dysplasia, epiglottic entrapment, subepiglottic cysts, and previous laryngeal surgeries such as ventriculectomy, vocal-cordectomy, prosthetic laryngoplasty, and arytenoidectomy.

3. Exercising Over-Ground Endoscopy

Over-ground exercising endoscopy is now available to a wide variety of veterinarians, and this has improved our ability to definitively diagnose a greater proportion of horses with upper respiratory tract disorders prior to surgery. In the past, it would be fair to say that the majority of horses undergoing respiratory surgery had a diagnosis made using an educated guess of the most likely pathology present, based upon their history and results of resting endoscopy. In some cases, the driver's influence, changes in head and neck position, the track surface, or running in company are key to reproducing the respiratory obstruction, and over-ground endoscopic examination is the only way to make a diagnosis. Similarly, over-ground endoscopy has lent itself to use in situations that were hitherto unheard of—such as when horses are show jumping or during Standardbred racing.¹⁴ Theoretically, more targeted treatment should improve our surgical success rates, although this remains to be seen.

There are many variables that can affect the examination protocol for over-ground endoscopy,

which subsequently affect the diagnoses and management of individual cases. Problems include trainers who are unwilling to work their horses fast to simulate race conditions because of the perceived risk of injury, doing multiple runs up short training tracks rather than exercising continuously over a longer distance (equivalent to race distance), and lack of an incline at some training gallops. If the exercise test is not a true replication of conditions experienced during competition, false-negative findings can occur.

For clinical researchers, using postoperative exercising endoscopy to evaluate a response to treatment is far preferable to using a proxy measure of the postoperative absence of disease, such as racing performance, or subjective assessment of success using clinical parameters such as reduction in respiratory noise, both of which may be influenced by numerous other factors. Cross-sectional studies investigating the appearance of the pharynx and larynx during exercise in horses that have previously undergone laryngoplasty have revealed important new information.^{15–19} Other such studies following up different upper respiratory tract surgeries are in progress^{20,21} and will be imperative for assessing these procedures in an objective way.

Dynamic Laryngeal Collapse

Dynamic laryngeal collapse is most commonly associated with recurrent laryngeal neuropathy (RLN), and principally affects the left side of the larynx arytenoid function at exercise is graded at A–C using the Havemeyer system (Table 1), and it has recently been proposed to add an additional grade (D) to differentiate between horses with relatively stable arytenoids that are held in the cadaveric position (C) from those which are unstable and are “sucked” across into the contralateral rims glottidis²² (grade D). Vocal-fold collapse is also categorized as a form of dynamic laryngeal collapse.

Palatal Dysfunction

Palatal dysfunction at exercise incorporates the syndromes of DDSP and palatal instability (PI).^{9,23} Although diagnosing DDSP during over-ground endoscopy is generally clear cut, diagnosing PI is relatively subjective. PI has been shown to negatively affect ventilatory parameters in exercising horses²⁴ and observation of PI is sometimes described as equivalent to a “presumptive” diagnosis of DDSP.²⁵ However, not all equine clinicians are in agreement that the two disorders are linked, because DDSP may occur without being preceded by PI. It is also unclear what degree of exercise-related soft-palate instability can be regarded as normal or physiological, and what percentage of horses diagnosed with PI on exercising endoscopy might experience DDSP under different conditions, such as racing.

Medial Deviation of the Ary-Epiglottic Folds

This condition was previously referred to as axial deviation of the ary-epiglottic folds,²⁶ but it has now

been suggested that medial is the correct term as axial and abaxial should only be used with reference to the appendicular skeleton²⁷ (*Nomina Anatomica Veterinaria*). The ary-epiglottic folds in the horse do not have a muscular component to them, in contrast with other species. Medial collapse is seen in horses at fast work, can cause significant obstruction,²⁶ and is often associated with other abnormalities such as DDSP.²⁸

Nasopharyngeal Collapse

Nasopharyngeal collapse has also been referred to as *nasopharyngeal obstruction* or *pharyngeal wall collapse*, and is characterized by ventral displacement of the dorsal wall of the nasopharynx or axial displacement of the lateral pharyngeal walls, occurring during early inspiration.²⁹ It is rarely diagnosed as a standalone condition, being more frequently observed in complexes of upper airway obstructions.³⁰ It has also been implicated as a precursor to forms of DDSP.²⁹ In fact, DDSP has been considered a type of pharyngeal collapse (because the soft palate constitutes the ventral wall of the nasopharynx), along with collapse of the nasopharyngeal roof and dorsal elevation of the epiglottis.²⁹ A grading system for nasopharyngeal collapse was proposed by Boyle et al.³⁰

Ventro-Medial Luxation of the Apex of the Corniculate Process

This describes the collapse of one corniculate process beneath the contralateral one during resting and/or exercising examination.^{31,32} It has been suggested that this is an unusual manifestation of RLN, or an advanced stage of adductor muscle dysfunction during the progression of RLN before full abductor dysfunction is appreciable.³¹ Abnormalities of the interarytenoid ligament³² or of the constitution of the corniculate process of the arytenoid cartilage have also been proposed.

Other Abnormalities

Uncommon abnormalities that can be identified with exercising endoscopy include a range of dynamic abnormalities seen as part of the laryngeal dysplasia complex, cricotracheal ligament collapse, epiglottic retroversion, and intermittent epiglottic entrapment among others.

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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Laryngeal Surgery and its Complications

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1. Introduction

The challenge of laryngeal surgery is to create a large stable airway that can be maintained under high negative pressures, while also maintaining the functional ability to close or protect the airway during swallowing. These somewhat-conflicting goals lead to the fairly high rate of complications associated with laryngeal surgery relative to other types of surgery. This also makes resolving complications with laryngeal surgery more challenging. Like any surgery, having a good understanding of the potential sand traps can minimize the risk of complications.

2. Recurrent Laryngeal Neuropathy

One of the most common abnormalities prompting laryngeal surgery is recurrent laryngeal neuropathy (RLN), often referred to as laryngeal hemiplegia. Determining a definitive diagnosis of RLN prior to deciding on a method of treatment may seem easy but can be difficult in the milder conditions. Mild arytenoid chondropathy and mild laryngeal dysplasia are frequently mistaken for RLN and if improperly diagnosed can lead to potentially inappropriate treatment. A critical resting endoscopic examination evaluating structure and function, in conjunction with physical examination findings are usually all that is necessary to make the correct determination. Other ancillary procedures such as ultra-

sonography or magnetic resonance imaging can be helpful if there is any question.^{1,2} Furthermore, dynamic endoscopy can be useful in determining the degree of obstruction for any of the above-mentioned disorders and will allow the abnormality to be seen in the appropriate context of the stress on the upper airway with the expectations for the horse postoperatively. In other words, with dynamic endoscopy you can see that a moderate degree of RLN based on resting endoscopy will likely result in less clinically significant respiratory compromise for a jumper than a racehorse. Yet, it should also be kept in mind that severity of the disease may progress over time, and while a recommended treatment may be effective at the initial evaluation, it may not be effective several months later.

Once a diagnosis of RLN is made, the proper course of treatment is still debated—either by vocal cordectomy or a method of laryngoplasty.³⁻⁵ The reported success rate of the laryngoplasty varies widely.⁶⁻¹¹ Successful results vary depending on the outcome variable evaluated and the breed or occupation of the surgical population. Thoroughbred racehorses generally have a lower success rate relative to non-racehorses, which is likely a reflection of the relative demand on the upper respiratory tract. This difference in conjunction with the relative risks and costs of the procedures will affect the decision to pursue one treatment over another.

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Complications Associated with Laryngoplasty

The likelihood of complications is significantly reduced with increasing surgical laryngoplasty experience. A thorough knowledge of surgical anatomy and understanding of the mechanical forces involved is essential for maximizing the probability of successful abduction. Despite this the most common complication of laryngoplasty is loss of abduction.

Loss of abduction can be seen in the immediate postoperative period, or progressively over several months postoperatively.⁹ Intraoperative endoscopy during suture placement will allow for the degree of abduction to be carefully controlled. Also achieving abduction with a standing awake animal may be beneficial in assessing the degree of abduction.¹² Yet the degree of abduction achieved at surgery is an inexact science. Although greater abduction has been associated with a greater likelihood to return to work and improved performance it has also been associated with higher rates of complications⁷ and there are several potential sources of immediate abduction loss. Suture pull-through at the cricoid or muscular process and suture loosening associated with anatomical variability are likely most common.¹³ Regardless of the specific cause (which often can only be speculated with individual cases), a large percentage of horses are expected to lose some abduction postoperatively.⁹ Methods have been implemented to minimize the postoperative abduction loss.¹⁴

Postoperative aspiration is the next most common serious complication associated with laryngoplasty. Although the degree of abduction likely is a factor in the risk of aspiration, surgical technique can also affect the horse's ability to swallow appropriately. If a horse experiences aspiration in the immediate postoperative period, particularly if there is "excessive" abduction, it is advised to allow time for abduction loss that may mitigate the problem. If aspiration persists, further procedures to protect the airway or reversing the laryngoplasty should be considered.

3. Epiglottic Entrapment

Entrapment of the epiglottis with a fold of sub-epiglottic tissue is a common abnormal finding in racehorses, and infrequently seen in non-racehorses.¹⁵ Although in non-performance horses it is usually associated with coughing; it is often associated with poor performance in racehorses. Yet, thin uncomplicated entrapments in themselves do not cause significant respiratory obstruction¹⁶ so there is some presumption that any poor performance subsequent to entrapments is associated with secondary intermittent displacement of the soft palate during exercise.¹⁷ Axial division of the entrapping tissue without sub-epiglottic resection is currently advocated in most conditions. Laryngotomy and excision of redundant tissue, which has been performed historically, should be avoided in uncomplicated cases of entrapment due to a lower

postoperative prognosis for racing successfully (27%) in comparison with axial division.¹⁸ There are multiple methods of surgical division, each with inherent risks. Surgical trauma to adjacent soft-tissue structures can be performance limiting, and infrequently the entrapping membrane can result in epiglottic deformation that is performance limiting even before any surgical intervention.

4. Arytenoid Chondropathy

Arytenoidectomy is most commonly performed for treatment of arytenoid chondropathy or less frequently for failed laryngoplasty. It is well accepted now that a partial arytenoidectomy is the preferred form of arytenoidectomy with varying descriptions of the technique and varying results.^{19–22} Success in racehorses is reported in 60–80% of cases.^{22–23} Experimental evidence shows that partial arytenoidectomy closely restores most respiratory mechanics to normal, but not all respiratory parameters are returned to normal.^{19,24}

The most common postoperative complication is poor performance. Poor postoperative performance can be secondary to an inadequate airway and possibly some degree of lower airway inflammation from dysphagia. Creating an adequately sized dynamically stable airway without any aspiration is challenging. Cytological evidence of lower airway inflammation has been reported in almost all cases postoperatively.¹⁹ Presumably, surgical techniques that minimize soft-tissue damage will limit the disruption to swallowing and decrease postoperative dysphagia. Another factor which could adversely affect airflow is the presence of intralaryngeal granulation tissue. Horses should be evaluated postoperatively and any intralaryngeal granulation tissue can be removed by transendoscopic laser surgery at that time. Delay in removing any tissue that is present may result in a more cartilaginous mass that is difficult to remove at a later date. In one study that a mucosal flap was employed, 17% of the horses had intralaryngeal granulation tissue that warranted laser resection.²³

The final postoperative complication that should be considered is airway noise during exercise. There is only one report that comments on noise in the post arytenoidectomy patient. They report abnormal noise in most patients.²¹ Given that even in the best case scenario the airway will no longer have normal contour, it is not surprising that abnormal respiratory noise is present in the exercising horse. Clearly if there is extraneous soft tissue that can dynamically deviate into the airway on inspiration the noise will be worse, but it is possible that the horse can still perform without significant airway obstruction and sound abnormal.

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The Author has no conflicts of interest.

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Microchips 101

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1. Introduction

The need to identify individual animals to prove ownership has origins dating back to the ancient Egyptians. Among the ancient Romans, the symbols used for brands were sometimes chosen as part of a magic spell aimed at protecting animals from harm.¹ By the European Middle Ages, hot brands were commonly used on cattle to identify ownership, especially in nations with large cattle-grazing regions such as Spain. These European traditions were imported to the Americas and were further refined by the *vaquero* tradition of the southwestern United States and included the branding of horses in order to trace animals back to specific ranchers or owners. In the 1950s the federal government required identification of animals being transported to different states. In the 1980s the United States Animal Health Association stressed that animals be individually identified in order to trace them back to the owner in case of emergencies or disease outbreaks. Today, equine identification and traceability are core fundamentals for every facet of the equine industry. Identification is defined as the verifiable evidence of a horse's identity. Traceability is defined as the ability to use individual unique identification to track a horse in all areas of its life from birth to death.²

Accurate, verifiable, permanent, unique individual identification of horses helps to ensure the accu-

rate registration of horses and ensures the rules of a competition such as age or class restrictions for the horse showing or racing are being met, promotes sports integrity, which ultimately leads to consumer confidence. Implementing accurate unique horse identification on certificates of veterinary inspection (health certificates) assist in biosecurity and disease-control efforts, specifically enables governing bodies to rapidly identify horses that may have been exposed to an infected horse at an event. In addition, horse welfare is of the utmost importance to the industry, and proper identification and traceability of horses enables authorities to hold horse owners accountable in cases of neglect and cruelty. In cases of a natural disaster or theft, properly identified animals can be promptly reunited with their owners when found. Verification of the horse's identification at the time of sale prevents fraud as it assures the buyer of the horse's true identity.

Currently, there are multiple methods of equine identification, each with its own unique advantages and disadvantages. Popular ones include official identification documents, such as breed registration papers, certificates of veterinary inspection, physical description, photographs, lip tattoos, brands, DNA tests, iris scans, and microchips. According to a National Animal Health Monitoring System Equine 2005 study, the most common forms of equine identification (ID) were registration papers

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(61.7% of operations and 47.8% of equids) and Coggins tests papers (40.0% of operations and 27.2% of equids). The least common forms of unique ID were microchips (3.1% of operations and 1.5% of equids). Freeze brand and hot-iron brand were used as unique IDs on 13.8% and 12.2% of operations. Of the 3.9% of operations that had “other” unique IDs, DNA and blood testing were common forms of identification.³

Physical description incorporates the horse’s age, breed, sex, coat color, markings, whorls, cowlicks, scars, and chestnuts. One disadvantage of a physical description as a unique identifier is these features may be subjective and differ depending on who is describing the horse. Many times, written descriptions lack detail, which leads to ambiguity. In addition, many horses look alike as they may be solid colored with no distinguishing markings. Therefore, a written physical description would not be sufficient in identifying individuals. For example, a written physical description is unable to distinguish a group of 3-year-old black Friesian fillies.

Another method currently used to identify horses is branding with either hot-iron or freeze-brand technique. The hot iron is an invasive procedure that produces a third-degree skin burn and localized skin necrosis.⁴ Freeze branding utilizes a branding iron that has been chilled with a coolant such as liquid nitrogen or dry ice. Rather than burning a scar into the animal’s skin, a freeze brand damages the pigment-producing hair cells, causing the animal’s hair to grow white where the brand was applied. Freeze brands, if applied properly, cause less damage to the animal’s skin than hot-iron brands and are usually more visible. An advantage of branding is that it is relatively inexpensive and generally difficult to alter. However, the technique comes with disadvantages, including pain, stress, and inherent safety issues associated with the procedure. In addition, brands are sometimes unsightly and difficult to read, and may be used to identify an owner or registry, not an individual horse. However, unique freeze brands have been used by the Bureau of Land Management to identify individual horses and the United States Trotting Association has used unique freeze brands to identify racing Standardbreds in recent years.

Since the late 1800s, lip tattooing has been used as a means of identifying individual horses. This method was adopted by the Jockey Club in the early 1900s to eliminate cheating and is applied inside the upper lip of the horse. Lip tattoos are currently being used in Thoroughbreds, racing Quarter horses, and Standardbreds. A Thoroughbred tattoo has one letter, which indicates the year of birth, followed by four or five numbers. Horses foaled outside North America will also have an asterisk (*) at the beginning of the tattoo. A Standardbred tattoo always has five characters, either a letter and four numbers or two letters and three numbers. The first letter in the tattoo indicates the year of

birth. A racing Quarter Horse tattoo has four or five numbers followed by a letter, making it easy to tell from a Thoroughbred tattoo. Some advantages of lip tattooing are that lip tattoos are permanent and difficult to alter. However, the lip tattooing procedure is invasive and has the potential to spread diseases, such as equine infectious anemia and equine piroplasmiasis. In addition, as the horse ages, the lip tattoo can fade and become difficult to read. There is also a potential that a lip tattoo can be altered so that they are completely illegible.⁵ The Jockey Club has a free tattoo lookup and research service called Interactive Registration at www.registry.jockeyclub.com as well as a *Tattoo Frequently Asked Questions*, which includes a video on how to read a lip tattoo. You can look up a Standardbred tattoo online at <https://pathway.ustrotting.com> and you can get information about Quarter Horse tattoos at www.aqua.com/racing/pages/hoseman-info/tattooer/identifier.

Newer noninvasive techniques for equine identification include iris scanning developed in 2000 by Japanese researchers. An infrared camera is used to map the unique pattern of the iris of the eye, which is then translated into an alphanumeric code. The code then serves as the horse’s identification number. This technology is beneficial given that it is highly accurate, noninvasive, and has a low probability of being altered, except with damage to the eye. Unfortunately, the technology is relatively expensive and there is limited access to reading equipment.

DNA typing using hair samples is another commonly used way of identifying individual horses. It is most commonly used by breed registries for parentage verification of foals. The DNA of each horse contains a unique genetic code that can be measured by gel electrophoresis and computer analysis. The advantages of DNA individual horse identification are accuracy and limited invasiveness. However, DNA testing is expensive and does not outwardly identify the horse.

Microchips are a relatively new form of individual unique horse identification that are highly accurate, convenient, with minimal risks of transmitting disease and impossible to change. On the downside, they are invasive and microchip readers may be considered relatively expensive. However, microchipping could be the best technology for the future of unique equine identification and as such are the focus of this paper.

2. Discussion

Veterinarians play an important role in microchipping horses as they are often called upon to insert the microchips and often to register them. Therefore, it’s important that they be knowledgeable on the use and capabilities of microchips. This paper will serve to provide that information. Microchips used in horses come in various sizes and materials but share a common appearance. The structure of the microchip includes the E-Unit, or “intelligent” portion of the microchip, which consists of a passive

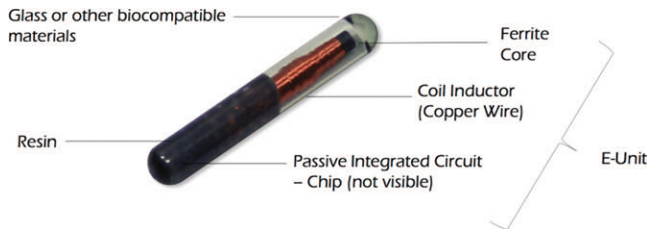


Fig. 1. Common equine microchip structure.

integrated circuit (IC), a coil inductor, and a Ferrite core. This component transmits the radio frequency signal, which is received and read by a microchip reader. The E-Unit is housed within resin and a biocompatible material, such as glass or polypropylene. Most of the microchips used in the horse range in length from 8 to 13 mm and width of 1.4 to 2.1 mm. The microchips are typically administered using a 12- to 15-gauge needle, depending on the specifications of the microchip. A detailed view of a standard equine microchip is detailed in Fig. 1.

Equine microchips are radio frequency identification devices (RFIDs) that are inactive until stimulated by a microchip reader. Once the power button on the microchip reader is pushed, it emits a low-frequency radio wave that activates or wakes up the microchip. The microchip then responds by transmitting the number embedded in the IC unit and the number is detected by the reader. This two-way communication is classified as full duplex communication, which is different from the half duplex, which is the one-way communication commonly found in cattle ID tags. Cattle ID RFID devices transmit a signal constantly.

The radio frequencies utilized by the microchips in horses are low frequency, between 120 and 140 kHz that can only be read by a scanner held within 10 centimeters of the chip. In comparison, some livestock RFIDs utilize the ultra-high frequency of 1 GHz which increases read range distance to 15+

feet. To assure quality in manufacturing of microchips, the International Organization for Standardization (ISO) and the International Committee for Animal Recording (ICAR) developed a set of standards for microchips used in animals. To be marketed as an ICAR/ISO-compliant microchip, the chip must meet ISO Standards 11784 and 11785. ISO 11784 references the microchip's unique numeric 15-digit code, whereas ISO 11785 specifies how the transponder activates and transmits information. The unique code structure consists of a header, which is used to assist the reader in finding the microchip, an identification code, which includes the unique 15-digit code for the individual animal, and a series of cyclic checks followed by an extension portion that can include other microchip features such as biothermal data or data storage. This code structure is illustrated in Fig. 2.

The identification code contains the manufacturer or country code (three digits), followed by a unique identification code (12 digits). The 15-digit code relayed to the reader represents the unique individual horse identification number. Each country has a country code, which for example is 840 in the United States, 276 in Germany, 056 in Belgium, etc. If the microchip is not correlated with a specific country code, a manufacturing code beginning with 9 is used. The 900 code is a designated shared code, and 999 is used for research or special use. Due to the potential for duplication numbers and the lack of association with a specific country or manufacturer, the use of shared 900 manufacturing code microchips in horses is discouraged. The 15-digit microchip containing a 12-digit identification code is guaranteed to be unique in ISO-certified chips and can therefore be verified as a unique identification code for the individual horse that receives the microchip. ICAR compliance also requires that microchips can be read by all ISO readers at 134.2 kHz, ensuring that information is standardized and universally avail-

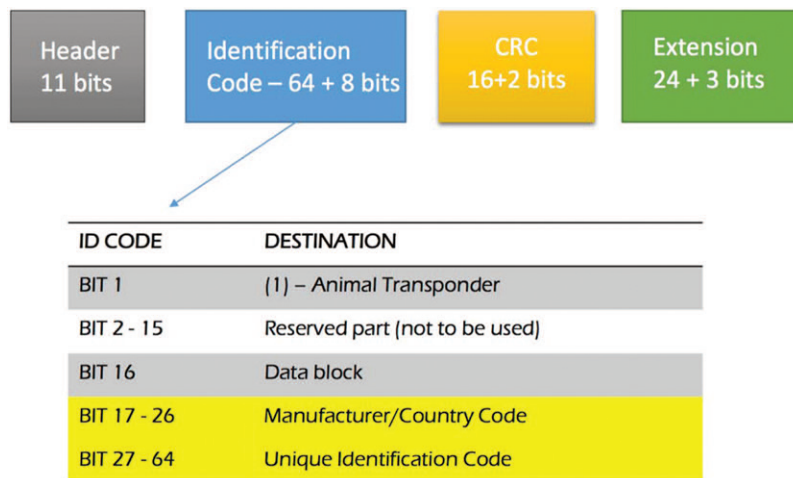


Fig. 2. ICAR/ISO Compliant Equine Microchip ID code as defined by ISO Standard 11784.

able as they are universal readers capable of reading all ICAR-compliant 15-digit microchips. To manufacture ISO-standardized microchips, manufacturers must comply with the ICAR Certification of Conformance. This requires that they test the microchips at an ICAR-approved testing center and have signed the Code of Conduct to respect ISO regulations. It is important to note that not all microchip manufacturers are ICAR certified, and are therefore not required to meet ISO standards and so it is important to ensure that an ICAR-certified microchip is being used.

According to a 2015 United States Department of Agriculture (USDA) Baseline Reference of Equine Health and Management in the United States Survey, which was conducted in 28 states and included 71.6% of the equine population, only 3.4% of equine operations containing 1.6% of the equine population use microchips as an identification method.⁶ Although this population is small today, large equine organizations such as the United States Hunter Jumper Association and The Jockey Club are beginning to mandate the use of microchips for permanent equine identification.⁷

With the growing use of microchips in horses, there are many decisions to be made regarding standardization of the practice. One topic up for debate is the use of country-coded vs manufacturing-coded microchips. The use of an 840-coded microchip (country coded) would provide some assistance in equine traceability, since these microchips can be traced to the United States. Official 840 microchips fall under the jurisdiction of the USDA, which requires official 840 microchips that meet the ISO/ICAR standards. The use of official 840 microchips in the United States requires registration of the premise prior to the time of implantation. Although the premise ID requirement is beneficial from a traceability standpoint, the concept has stimulated pushback in the equine industry given that many horse owners are reluctant to share personal information, such as their physical address. Entities such as breed registries and racing venues have worked around the issue by assignment of microchips to the premises of the breed registry or the racetrack. This eliminates the assignment of the microchips to the horse owner's premises. The use of microchips with the manufacturing code beginning with a "9" does not require a premise ID. These microchips trace back to a specific manufacturer instead of the premise where it was administered. Microchip numbers beginning with 9 could be tied to the horse's registration papers, show papers, Coggins tests, etc. and could be filed with the breed association.

Given the permanence of microchips once implanted into a horse, correct implantation technique is important. Currently, guidelines for microchip implantation are intended for administration by veterinarians or in accordance with state laws. In most cases, sedation is not required, although local

anesthesia applied prior to implantation is often utilized. Prior to inserting the microchip, it is important to scan the horse first to identify whether a microchip has already been implanted. A universal reader should be used that can identify various frequencies, and the user should be familiar with the reading distance of the reader. The horse should be scanned along the left side of the horse's neck from poll to withers in a parallel and perpendicular motion that includes the entire neck. Be aware that some Thoroughbred racehorses in Canada have the microchip inserted in their upper lip so that areas should be also scanned in these horses. If a microchip is not detected, the technician can move forward with the microchip administration. Correct microchip administration technique is outlined as follows:

1. Scan microchip inside packaging to ensure correct code.
2. Identify correct placement in the nuchal ligament on the left side of the neck, halfway between the poll and withers, and approximately 1.5 to 2 in below the mane.
3. Aseptically prepare the implantation site.
4. Remove administration needle from packaging and remove needle cap with bevel facing up.
5. Insert needle perpendicularly to the horse as an intramuscular injection.
6. Once completely inserted, depress plunger and remove the needle.
7. Scan the horse again to ensure correct microchip placement.

Some minor health concerns are possible following microchip administration, including pain or inflammation at the implantation site and migration of the microchip. These health factors have been investigated in several research projects. In 2007, Gerber et al⁸ investigated the inflammatory and pain response associated with microchip administration. Skin temperature, swelling area, and pressure threshold were measured for 2 weeks following implantation of a microchip. Results of the study indicated swelling and sensitivity were apparent for up to 3 days following microchip implantation.⁹ Another study by Gerber et al investigated migration probabilities of microchips at 1, 2, 4, and 6 months after implantation.⁸ Radiographs measuring the distance between the most cranial point of the fourth cervical vertebrae and the microchip indicated the microchips did not migrate. A similar study by Stein et al⁹ investigated the incidence of microchip migration in horses, donkeys, and mules over a 4-year period. There was no evidence of microchip migration at the conclusion of the study.⁹ Therefore, investigations indicate that microchip administration yields minor pain and inflammation at the injection site and microchip migration should

be minimal following the correct implantation in a horse.

An additional feature available in some microchips is temperature-sensing technology. Currently, marketed equine Biothermal microchips are ISO 11784– and 11785–compliant identification devices, but can also report an animal's body temperature whenever the device is scanned. The original technology yielded inconsistent results, so the chip has been recalibrated to improve accuracy. The current technology is calibrated to an ideal temperature of 38°C to give more consistent readings. A study by Langer and Feitz¹⁰ evaluated the reliability of microchip temperature readings when measured every 30 seconds. Results indicated that the accuracy was within $0.07 \pm 0.12^\circ\text{C}$.¹⁰ Similar studies performed in foals and performance horses yielded similar results. Anecdotal reports by veterinarians using thermal chips indicate that ambient temperature and direct sunlight on the horse may affect the accuracy of thermal chips and should be taken into consideration when recording results. Given that biothermal chips can be scanned frequently with ease and are accurate in demonstrating temperature changes over time or trends, they are a valuable option as a monitoring tool for equine health.

3. Conclusions

At a recent US Animal Health Associating and National Institute of Animal Agriculture sponsored Equine Identification Forum attended by representatives from the breed associations, regulatory agencies, veterinarians, owners, and microchip companies, the general consensus was that now is the time to advance equine identification and traceability. The attendees also agreed the identification technology and software to manage data from microchips is available and ready to be used but there is little support for a national database. Rather, individual breeds and disciplines will be charged with maintaining show/race records. There was support for a search engine much like that used by the American Animal Hospital Association in small animals, that would allow input of the horse's microchip number in order to connect horses lost due to theft or natural disaster

with their owner. The presentations and white paper from the forum can be found at <https://animalagriculture.org/proceedings/equineidforum>. A working group has been formed to identify, develop, and implement a strategy for advancing equine identification.

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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.

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Traceability of Equine Microchips

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1. Introduction

For many years, equine practitioners, equine owners, and others have been implanting microchips into horses for the purposes of unique and unalterable identification. Although the safety, practicality, and usefulness of this practice has been well established, there is little information available about the actual traceability of equine microchips in the long term. Given that the life span of horses today is generally quite long, often up to 20 years or more, and that the percentage the U.S. horse population over the age of 20 years is steadily increasing (now comprising up to 11.4% of the total population),¹ it is clear that long-term traceability of equine microchips is necessary now and in the future.

Reasons for needing to trace a specific equine microchip at this time are limited, but vital when encountered. State and federal animal-health officials often need to use the microchip of a specific horse involved in a disease investigation to trace the horse's history and potentially identify additional exposed horses or equine premises. First responders to natural disasters who are tasked with collecting and managing displaced equids have significant challenges in identifying ownership of horses in these situations and need the traceability of microchips to return these animals to their rightful own-

ers. Individuals searching for a lost or stolen horse have a critical reliance on the potential traceability of equine microchips for the purposes of having their horse found and returned to them. Equine rescue groups often encounter horses that have lost their identity and endeavor to trace any unique identification associated with the horse, be it a brand, a tattoo, or a microchip in an effort to restore the horse's identity and uncover its history.

The current methods available for tracing an equine microchip are also limited, which presents a significant challenge. The scenarios described above each begin with someone scanning the horse in question and obtaining a unique microchip number. But what is the individual to do with this number now? How does one go about tracing this microchip? If the phenotype or known history of the horse itself presents some clue as to a specific breed registry or discipline group that might have information connected to the microchip, then that is often the best place to begin a search. If, however, there is no known entity with which to begin the inquiry, then the individual is forced to begin at the beginning; with the manufacturer of the microchip. Most commonly, the first three digits of the microchip number will indicate the manufacturer of the chip. The name and contact information for the manufacturer can be obtained online by looking up the three-digit code on

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the International Committee for Animal Recording (ICAR) Web site.² Upon contacting the manufacturer, a service representative can provide the searcher with the name and contact information for the distributor or company to which the manufacturer sold the microchip. The searcher must then contact the distributor or next entity in line and obtain the name and contact information for the group to whom they next sold the microchip and so on down the line until an actual entity is identified that maintains specific data on the horse in which the microchip was implanted.

Successful traceback of an equine microchip relies upon whether the searcher ultimately reaches an entity that had confirmed specific information about the horse in question and how long it actually took to acquire that information. Several case studies of actual attempted microchip traces are presented herein to demonstrate the current status of equine microchip traceability in the United States.

2. Case Study 1

A load of 10 adult horses in a trailer was intercepted in south Texas by the U.S. Department of Agriculture (USDA)–Animal and Plant Health Inspection Service (APHIS)–Veterinary Services (VS) in the process of being smuggled across the Texas-Mexico border. The horses were noted to be in poor body condition and the examiners were unable to agree on the likely breed of the horses, but routine radiofrequency identification (RFID) scanning as part of the examination revealed that most of the horses were implanted with microchips. The horses were confiscated and tested for dourine, glanders, equine piroplasmiasis (EP), and equine infectious anemia (EIA) as per official U.S. import protocols. All 10 horses tested positive for *Theileria equi*, an etiologic agent of EP, for which horses presented at official importation are rejected entry. The horses were euthanized as a result, but tracing of the microchips was attempted by APHIS-VS as part of the Investigative and Enforcement Services investigation of the illegal movement to ascertain the origin of the horses and potentially other individuals involved in the illegal movement.

Online lookup of the three-digit prefixes of the microchips on the ICAR Web site led to identification of the manufacturer.² Contact of the manufacturer by phone provided the identification of the distributor of the microchips, a company located in Europe. Telephone and email contact with the distributor in Europe revealed that the microchips had been sold to a breed registry in Spain, the Asociacion Nacional de Criadores de Caballos (ANCCE) de Pura Raza Espanola (PRE) breed registry. Perusal of the breed registry's Web site to find contact information for the group led to identification that the registry had an online microchip lookup page on their Web site.³ Search of the microchip numbers through the lookup page confirmed the intercepted horses to be registered Spanish PREs, born in Spain,

with several of the horses pictured at official shows in Spain just 2 years prior to their being intercepted in Texas.

This traceback was considered fully successful in that the entity with confirmed information on the individual horses was located and the time it took to acquire the information beginning from the first contact with the manufacturer was approximately 4 days. In addition, this particular traceback was eventually responsible for uncovering a long-standing route of illegal movement for Spanish PREs into the United States and also led to the identification of two additional EP-positive horses in California that had been previously smuggled from Spain via Mexico. The discovery that microchips of Spanish PREs registered with this particular breed registry can be directly searched on the registry's Web site was an additionally valuable piece of information should a microchipped horse with that suspected breed lineage and no other history available be encountered and need to be traced in the future.

3. Case Study 2

A grade stray horse was intercepted by APHIS-VS personnel on the Texas-Mexico border and physical examination including RFID scanning revealed the presence of a microchip. Although the horse was ultimately confirmed to be test negative for the U.S. import diseases of interest, it was necessary to trace the microchip in an attempt to locate the owner of the horse. With no obvious indication of a specific breed registry or other entity which may hold information on the stray horse, the traceback was begun with the manufacturer of the microchip. The manufacturer name and contact information was obtained by online lookup of the three-digit prefix of the microchip number on the ICAR Web site.² Telephone contact with the manufacturer yielded the name and contact information of the distributor to which the microchip was sold.

Telephone contact with the distributor led to several problems with continued traceback. First, the distributor asked if the microchip in question was a 2-mm chip or a 4-mm chip. Upon being informed that we did not know the size of the microchip and that it could not be visualized because it was still implanted in a live horse, the representative for the distributor was surprised by this information. He then clarified that the microchip in question was a wildlife microchip and was intended to be implanted into a fish. This was the first instance we had identified in which a microchip intended to be implanted into a different species was actually found in a horse. In addition, the distributor indicated that this particular chip was rather old and pre-dated their current company software by several iterations. In fact, the chip could only be searched in an outdated computer that the company kept in an unused corner of the office and which only the owner of the company knew how to access. Given that the owner of the company was only present in the office

1 day per week, arrangements were made for the chip to be searched in their old computer on another day and a callback was promised. Unfortunately, the callback 2 weeks later confirmed that the microchip was not found in the database of the old computer system and was deemed untraceable at that point. The time to determination that the microchip was untraceable was 2 weeks and the owner of the stray horse was never determined.

4. Case Study 3

A cluster of 17 EP-positive bushtrack (unsanctioned) Quarter Horse racehorses was identified on a premises in Tennessee with iatrogenic transmission confirmed as the source of spread through the owner/trainer's repeated reuse of an IV administration set between horses. Traceback of each of the infected horses to their previous owners/trainers/premises was needed in an attempt to identify not only the original source of the infection in the cluster, but also to find other horses that may have been previously exposed and required testing. In addition to lip tattoos present in some of the infected horses, two of the horses were also found to have microchips. Although most of the infected horses were suspected to have been officially registered as foals with the American Quarter Horse Association (AQHA) and the horses with lip tattoos were likely to also have previously been active in sanctioned Quarter Horse racing, all of the horses had since lost their AQHA registration papers and registered names along the way. Traceback of EP and/or EIA-infected racehorses has been most effectively carried out the past few years using registered names of horses and online race history lookup through Equibase.⁴ Without the registered name of the infected horse, the finding of previous owners and trainers and ultimately identification of other exposed horses that need to be tested is often unsuccessful.

In this case scenario, the quickest and most effective way to approach individual traceback of the infected horses in question was via the lip tattoos. Contact directly with AQHA for identification of the registered names of some of the horses with lip tattoos was conducted and a few of the horses were restored to their official identification through this method. The time to confirmation of a horse's identity through lip tattoo was very short and took usually only 1–3 hours. Unfortunately, several of the horses with lip tattoos had evidence that their tattoos had been specifically altered and/or tattooed over previously in an apparent attempt to change or conceal the identity of the horse. Most of the horses with altered lip tattoos could not ultimately be identified or traced. Individual traceback attempts on the two horses with microchips present is outlined below.

Case Study 3A

Traceback on the microchip of the first horse began with online lookup of the manufacturer on the ICAR

Web site using the three-digit prefix of the microchip number.² The manufacturer provided information that the chip had been sold to a veterinary supply company which they knew to have since gone out of business. The manufacturer then provided the name and contact information for a second veterinary supply company that was known to have bought out the original veterinary supply company. Contact with the second veterinary supply company was difficult and circuitous; it took discussions with four different employees at the company over several days before an individual was identified who knew anything about the equine microchips being sold. It was then ascertained that no records from the original veterinary supply company were maintained by the new company and the chip being searched was deemed to be untraceable beyond that point. Out of curiosity, a query was made regarding whether the current veterinary supply company would be able to provide information on any of the specific microchips they currently sell. The answer was that the company maintained absolutely no records indicating to whom a specific microchip or series of chips was sold. Thereby, any microchip sold through this particular veterinary supply company would be immediately rendered as further untraceable.

Case Study 3B

Traceback on the microchip of the second horse likewise began with online lookup of the manufacturer on the ICAR Web site using the three-digit prefix of the microchip number.² The manufacturer provided the name and contact information of a small private distributor to whom the chip was sold. The distributor had no staff to answer the phone and a voicemail message was left for return contact, which occurred the next day. The distributor had excellent records and was able to provide the name and contact information for the veterinary practice to which the microchip had next been sold. Contact with the office manager at the clinic revealed that this was a small mixed animal practice and that no electronic medical records on any of the patients were kept, so the microchip number could not be searched electronically. The office manager offered to have the veterinarian return the call to investigate the matter further.

Since the state in which the veterinary practice was located is known to be one that uses microchips in connection with a state EIA program, an additional call was placed to the state animal health official's office in the hope that a search of the state database might locate the chip in question. A quick search of the state's database system yielded no matches to the microchip number being sought. When information was provided about the reported veterinarian likely involved in placing the chip, the state veterinarian commented that that particular veterinarian often did not send in their paperwork to properly record the chip with the state.

The veterinarian did return the phone call the following day, but was ultimately unable to locate any records associated with the microchip that he had purchased and implanted presumably for an official state EIA program. Even given additional information about the horse, whose registered name and previous owners had actually already been ascertained through his lip tattoo number, and the potential date range in which the veterinarian likely would have seen the animal, he was unable to find anything in his paper medical records that matched the horse. So, the traceback of this microchip number also reached a dead end with approximately 1 week lapsing from the beginning of the trace to the time when the chip was determined to be untraceable.

5. Conclusions from the Case Studies

The above case studies and many similar attempts at tracing equine microchips for state and federal regulatory purposes over the past few years have highlighted some significant challenges. There are multiple parties involved in and expectedly responsible for keeping records associated with the life of an equine microchip. Failure to either keep or transfer records at any single step in the pathway yields a permanent dead end to the traceability of the microchip, rendering it almost essentially useless. So far, the best outcomes in tracing a microchip have been achieved when the end information is maintained by breed registries or other equine industry groups that have a vested interest in connecting data for the individual horse to its unique identification. Although in nearly all instances, contact with the manufacturer has been successful in obtaining the next distributor or entity to whom they sold the specific microchip, traceback in a step-wise manner beginning at the chip manufacturer is time consuming and is not practical in the event of an urgent traceback need, such as a highly contagious disease outbreak. The revelation that some microchip manufacturers are not meeting their international industry standard of requiring their distributors to maintain records on each microchip sold is a crippling inadequacy that must be rectified. Finally, it seems clear that a publically accessible interactive online microchip lookup tool for equine microchips is desperately needed to streamline the traceback process. Such a lookup tool could provide quick identification and contact information of the official entity or group (breed registry, discipline group, state/federal program, etc.) that maintains information related to that particular microchip number while maintaining the security and confidentiality of that data until a specific request or need is presented and considered for information disclosure.

6. The Future of Equine Microchip Traceability

In January 2017, the National Institute for Animal Agriculture and the U.S. Animal Health Association

jointly hosted an Equine Identification and Traceability Forum in Denver, Colorado. More than 100 individuals attended the forum representing state and federal animal health officials, microchip manufacturers and distributors, and leaders of equine industry organizations. Although a comprehensive summary of the meeting outcomes are still forthcoming, overall conclusions included that microchipping should be the goal for universal equine unique identification and that this goal should be an equine industry-driven initiative. Also presented was the idea that individual equine industry entities or “silos” should maintain and protect their own data and that an online equine microchip lookup tool indicating which “silo” or “silos” maintains the data pertaining to that microchip would be a safe and effective method for microchip lookup and traceback.

Several equine industry initiatives have already begun which support these long-term goals. The Jockey Club has implemented microchipping as a requirement of registration for Thoroughbred foals born in 2017 and thereafter. The U.S. Equestrian Federation has a series of initiatives proposed which will eventually require a microchip for participation in their sanctioned events. The U.S. Trotting Association is conducting a test program to use microchips for identification of Standardbred racehorses in place of the current lip tattoos or freeze brands. Other breed and discipline groups are entering into active discussions regarding the future of equine microchips as part of their programs.

Also now available is an online equine microchip lookup tool created by Microchip ID Systems, Inc. and intended in the future to be hosted by an impartial third party outside of the microchip-manufacturing industry.⁵ This lookup tool is publically available and accessible online free of charge. Although the current version of the lookup tool is not yet linked to any equine industry databases, it does now provide one-step access to the name and contact information for the manufacturer of the microchip number being searched without the need to visually search the list of manufacturer codes posted on the ICAR Web site. In the future, it is hoped that equine industry groups would allow for their databases to be securely “pinged” by the microchip lookup tool in search of a specific microchip number. If the number is found, the lookup tool could display the equine industry group name and contact information whereby the searcher could directly contact the group and request assistance with tracing of a specific microchip. Above all it must be recognized by the equine industry that simply implanting microchips in horses is not enough. There must be maintenance of data and structure of traceability built-in behind the microchips for their intended purposes to be fulfilled.

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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Biosecurity at Events and on Farms: Routine and Disease Outbreak

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Biosecurity is essential for protecting the future of the equine industry. Veterinarians play an important role in biosecurity assessments, development of biosecurity plans, and implementation of biosecurity measures. This paper provides tools for performing risk assessments and implementing biosecurity measures. Ultimately, collaboration and communication on biosecurity between equine private practitioners and the equine industry are essential for protecting and promoting the health of the U.S. equine population. Author's address: California Department of Food and Agriculture, Animal Health Branch, Equine Programs 1500 W. El Camino, #215, Sacramento, CA 95833; e-mail: kflynn@cdfa.ca.gov. © 2017 AAEP.

1. Introduction

Biosecurity practices heavily affect the epidemiologic triad of host, agent, and environment. These biosecurity practices target the ecology of the animal and human population, the characteristics of the pathogen, or the complexity of environmental evolution and diversity. Veterinarians should routinely perform biosecurity practices to decrease risk of disease transmission (i.e., cleaning and disinfection of equipment between uses, properly disposing of needles and syringes after single use, performing hand hygiene, and assuring the cleanliness of footwear and clothing); however, these individual actions are not currently recognized as the standard of practices by all members of the equine industry.^{1,2}

Trends in equine management are transitioning to expansive transportation of horses and intensive commingling of horses in confined spaces that have undoubtedly increased the risk for introduction and transmission of infectious agents. In evaluating the industry need for enhanced biosecurity at equine events, it is useful to consider the 2011 equine her-

pesvirus-1 (EHV-1) multi-state outbreak associated with horses having attended National Cutting Horse Association Western National Championship in Ogden, UT. According to the U.S. Department of Agriculture, Animal Plant Health Inspection Services, Veterinary Services, published case-control study, the risk of equine herpesvirus myeloencephalopathy (EHM) increased with the increasing biosecurity risks while at the Ogden Event. Some of the cited biosecurity risks included horses being tied in the barn, use of shared water, and use of communal wash racks.³

Biosecurity risks are not limited to equine events, but are also prevalent at large equestrian facilities. The January 2003 outbreak of the neuropathogenic strain of EHV-1 at the University of Findlay's Equestrian Center highlights some additional biosecurity risk factors associated with large equestrian facilities, such as changes in horse populations, unrestricted movement of horses within a facility, and environmental conditions leading to reduced ventilation in shared air space. Both incidents demon-

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strate the importance of biosecurity measures to protect the horse, to eliminate the infectious agent, and to improve the environmental conditions.⁴

The equine industry has always recognized the veterinarian as the trusted resource for information and guidance related to the health of the horse.⁵ The veterinary practitioner has a unique opportunity to educate the industry on the need and benefit of biosecurity plans. Equine veterinarians now have an expanded role in protecting the health of horses by performing biosecurity risk assessments, developing and implementing biosecurity plans, and routinely evaluating the plans.

The intent of this paper is to provide guidance and resources related to performance of biosecurity risk assessments, identification of appropriate biosecurity measures, and evaluation of biosecurity measures. The paper will provide guidance on routine biosecurity and enhanced biosecurity measures necessary for a disease outbreak investigation.

2. Biosecurity Risk Assessment

General Considerations

Similar to a physical exam of an individual horse, a facility can be assessed to determine the biosecurity risks it has based on current practices. The ultimate objective of a biosecurity risk assessment of a farm or event is to identify potential points of disease agent entry and potential points of disease-agent transmission on the premises. A risk-assessment site visit should include evaluation of the following:

- Premises layout
- Infrastructure and design (stabling, storage)
- Standard operating procedures (documented and observed)
- Equine turnout and exercise routines
- Equine movement within the facility
- Equine movement onto and into the premises
- Visitors and service providers to the operation
- Practices for delivery of feed and removal of manure
- Water and feed sources
- Control of wildlife and insects/ticks

Planning Risk Assessment Visit

Every facility is unique, so a biosecurity risk assessment requires a dedicated appointment for an onsite visit and assessment. All involved parties should understand the importance of the assessment, the objectives of the assessment, and the plan for the assessment. Key personnel to include in the risk assessment site visit are listed below.

- The facility owner
- The facility manager
- The event manager (for event grounds)
- Employee supervisors

Since the risk assessment will include observations of daily practices on a farm, the facility manager or

owner may consider notifying employees, trainers, horse owners, and riders of the planned site visit. Involvement of all stakeholders enhances stakeholder buy-in on the ultimate plan. The veterinarian should schedule and allot adequate time for the biosecurity assessment. The length of appointment will be dependent upon the size of the premises, the number of personnel to interview, and the complexities of facility management. The client should understand that the objective is to observe current routine practices, so practices should not change before or during the assessment visit.⁶

Before entering the premises, consideration must be given to the disease agents of concern; this is of importance for determining potential entry points and mechanisms of spread. Is the client interest for a biosecurity plan for one disease, such as equine herpesvirus-1, a plan for all endemic contagious diseases of concern, such as strangles, influenza, and equine herpesvirus-1, or a plan for equine foreign animal diseases, such as African Horse Sickness? The more inclusive and complex the needs of the plan, the greater the time investment necessary to address the disease agent entry and transmission points. Clearly outlining the parameters at the start of the visit will ensure that the final written biosecurity plan will meet the client's need. Veterinary knowledge and expertise are valuable, so charging for the time conducting the assessment, identifying and recommending biosecurity measures, and implementing the biosecurity plan is appropriate. A published article provides recommended pricing structure for work associated with biosecurity risk assessment and biosecurity plan development.⁷

Approach to On-Site Risk Assessment

The objective of the on-site risk assessment is to identify potential disease entry points and potential mechanisms for disease spread on the premises. Knowledge of the general transmission routes for the disease agent(s) of concern is useful during the assessment. Development of a systematic approach to the risk assessment assures evaluation of all critical areas.

The "follow-the-horse approach" starts with the arrival of the horse on the grounds and follows the horse through the facility until its departure from the facility. As management of horses may vary from trainer to trainer or by horse discipline, it may be necessary to follow several horses to determine the extent of the risk. This assessment approach is successful for evaluation of the equine event grounds during the show. However, care must be taken when evaluating an event grounds during non-competition times as the assessment is then based on assumption that the reported standard practices actually occur during an event.

For a farm, ranch, or boarding facility evaluation, the basis of the systematic approach may be on geographic divisions of the property or the manage-

ment divisions (i.e., divisions by trainer or owner). It is important to evaluate all areas of the premises, including grazing areas, pastures, turn-out facilities, hay fields, feed storage locations, and equipment storage areas.

The client copy of the final risk assessment report should include documentation and photographs of key observations made during the site visit.

3. Performing Risk Assessment

The transmission routes of the disease agents of concern are the basis for the various ways a disease agent may enter an equine premises. Once a disease agent gains entry to an equine premises, there may be various modes for disease transmission. Critical assessment for potential entry points of disease agents include the horses, animals, wildlife, people, trucks, equipment, feed, and supplies. Knowledge of the modes of disease transmission for the disease agents of concern is the basis for the premises risk assessment, which includes evaluation of the facility layout, the horse health protocols, points of animal-to-horse contact, points of human-to-horse contact, protocols for handling of manure, soiled bedding, hay handling and disposal, feed storage and handling procedures, traffic control, and recordkeeping.

Disease Agent Entry Risk Assessment

Based on the transmission routes of the disease agents of concerns, there are various ways for the disease agent to enter the premises. Key aspects to assess include the following:

1. *Horse entry:* Any horse entering the premises can be a potential source of disease agent entry given that the horse could be shedding the disease agent if precautions are not taken to manage the potential risk they pose. When assessing the risks of horse entry, the goal is to document the following:
 - a. The origin of horses entering (i.e., sales auction, equine event, private facility, etc.)
 - b. The mode of entry (i.e., transported onto premises or ridden onto the premises)
 - c. Documentation requirements for entry to the premises (i.e., certificate of veterinary inspection, owner/agent health declaration, etc.)
 - d. Diagnostic test requirements for entry to the premises (i.e., equine infectious anemia (EIA) test, strangles testing, etc.)
 - e. Entry inspection protocols (i.e., physical examination of horse upon entry), and
 - f. Destination stabling for newly arriving animals (i.e., isolation stabling, designated stabling with cohort animals, any open stall, etc.).
2. *Other animal entry:* Animals entering the premises can act as mechanical or biological vectors. Document observations of the location and number of pets, feral animals, live-

stock, poultry, and feral animals. Identify and document potential points of animal entry to the facility, such as incomplete perimeter fencing, lack of an entry gate, a consistently open entry gate, or regular shipment of livestock or poultry.

3. *Wildlife entry:* Wildlife, such as rodents, birds, wild cervids, opossums, and raccoons may carry disease agents onto the premises. Assessment and documentation for wildlife entry should be similar to domestic animal entry.
4. *Human entry:* Many people visit equine premises each day. Accurately recording the categories of people that enter the premises is essential for identifying potential sources of disease-agent introduction. Typical categories of people entering an equine facility include the horse owners, facility employees, veterinary professionals (veterinarians, technicians, and assistants), horse-care professionals (groomers, massage therapists, chiropractor, farriers, dentists, etc.), industry representatives (nutritionists, pharmaceutical representatives), and supply delivery personnel (feed, shavings, hay).
5. *Vehicle entry:* Vehicles can carry a disease agent to a premises on the tires, on external surfaces, or in the load being carried. Observation and documentation of vehicle entry on to the premises should be performed for all the categories of personnel that enter the premises.
6. *Equipment entry:* Contaminated equipment can carry a disease agent on to a premises. Observation and documentation of equipment entering with all categories of personnel should be done.
7. *Feed, hay, and supplies entry:* Contaminated feed, hay, or supplies can carry a disease agent on to a premises. Documentation should include the source of feed, hay, and supplies, and any requirements for evaluating quality of these products entering the premises.
8. *Water sources:* Surface water presents a potential for risk because quality is difficult to assess and control, i.e., streams, irrigation ditches, lakes, ponds, etc.

Disease Agent Transmission Risk Assessment

Once a disease agent gains entry on to an equine premises, there are various modes of disease transmission. Knowledge of the modes of disease transmission for the disease agents of concern is the basis for the facility disease agent transmission risk assessment.

1. *Facility layout:* A complete biosecurity assessment of the facility should include the following:
 - a. Assessment of stalls (i.e., location, number, size, construction, sanitation, extent of horse-to-horse contact, etc.)

- b. Availability of an isolation area (i.e., location, access, suitability)
 - c. Feed and water areas (i.e., location, storage, access, handling)
 - d. Communal areas (i.e., location, separation, access, sanitation, construction, sanitation, extent of horse-to-horse contact, etc.)
 - e. Exercise areas (i.e., location, separation, access, sanitation, extent of horse-to-horse contact, etc.)
 - f. Parking areas (i.e., location, access, separation, signage). The assessment report should include a map of the venue, which designates stables, fence lines, traffic flow, water sources, and parking.
2. *Horse health protocols*: Horses shedding infectious disease organism on the premises are a risk to the other horses on the premises. To identify potential disease organism transmission risks, assess existing protocols for maintaining horse health plans, monitoring horse health, and isolating sick horses.
 3. *Animal-to-horse contact*: Assess the stabling area, paddocks, pastures, wash racks, and exercise areas for the potentials for horse-to-horse contact. Additional consideration should be given to locations where other animals have potential for direct contact with horses on the property. Document the locations for animal-to-horse contact and describe the frequency and duration of the contacts.
 4. *Human-to-horse contact*: The transmission risk depends on the frequency, duration, and location of contact (i.e., muzzle, head, neck, etc.). The frequency and duration of human interaction varies across equine properties. For example, employees responsible for cleaning stalls and/or feeding horses interact directly with multiple horses on a routine basis, whereas a trainer may interact directly with a subset of the population. To ensure complete assessment of potential transmission risks, the report should document any contacts with a horse on the property.
 5. *Manure, soiled bedding, and hay disposal*: Given that manure, soiled bedding, and hay have the potential to transmit disease organisms, the handling and disposal of these products influences disease transmission risks. Document the protocols and frequency of manure, soiled bedding, and hay removal from the stall, their delivery to the holding area, and their removal from the property.
 6. *Feed storage and handling*: Contamination of feed or hay with an infectious disease agent during the storage and handling of product is also possible. Evaluate feed and hay storage area location, security, and level of sanitation. Assess employee feed distribution protocols for disease transmission risk factors.
 7. *Traffic*: The movement of trucks, trailers, tractors, golf carts, wheelbarrows, and bicycles around an equine premises have the potential to spread infectious disease agents. Evaluate the types of vehicles and wheeled equipment that move around on the premises, the frequency of vehicle use, the locations of vehicle movements, and the sanitation practices on the vehicles.
 8. *Recordkeeping*: Review facility records for horse movements (entering, remaining on, and exiting the premises), location of individual animals, and horse health status procedures (monitoring and treatment records).
 9. *Written protocols*: For large operations with multiple employees, determine whether there are written instructions on what to do if there is a febrile horse, a horse with nasal discharge or a horse with signs of abortion, horses displaying diarrhea or neurologic disease on the premises.

Assigning Risk Levels

After identification of risk factors, classify the risks as high, medium, or low risk. The basis for the assignment of level of risk should be the potential for disease introduction and spread. Assignment as high risk would suggest that there is a very high likelihood of disease entry or spread, whereas a low-risk assignment would suggest there is a low likelihood for disease entry or spread. For example, stabling an arriving horse that has a nasal discharge and temperature of 102°F in the main stabling area would be a high-risk practice with a high potential for disease agent entry and transmission. Stabling the arriving horse with nasal discharge and a temperature of 102°F entry in the isolation area would be a moderate-risk practice, given that there is potential for agent entry to the premises, but the disease transmission risk is significantly lower with the current biosecurity protocol for isolation.

4. Implementing Biosecurity Measures for Identified Risks

General Considerations

Disease risks are inherent when animals commingle. The assessment may identify transmission risk areas that cannot be eliminated by a practical day-to-day routine biosecurity mitigation program. It is not feasible to eliminate all disease risks at an equine facility completely, so the client must determine the acceptable level of disease risk for their premises; the practitioner can then develop a risk-tolerant plan with policies and procedures suitable to attain the appropriate level of biosecurity. Implementing biosecurity measures to address risks may require a significant expenditure of financial and human resources. An enhanced biosecurity plan, for implementation during an infectious disease outbreak, can address the biosecurity gaps.

This section provides general biosecurity recommendations and resources to address the identified risks through implementation of biosecurity measures for routine use and/or in response to a disease outbreak.

Routine biosecurity measures generally focus on limiting horse-to-horse contact, limiting human-to-horse contact, avoiding sharing of equipment, tack, and grooming supplies unless cleaned and disinfected between uses, monitoring horse health, and isolating horses with clinical signs of disease. Enhanced biosecurity measures during a disease outbreak require stricter enforcement of all the routine measures and implementation of more costly and time-consuming disease-barrier precautions and disease-control measures.

Case Scenario

This scenario focuses on practical, implementable, real-world biosecurity measures for routine use and for use during a disease outbreak. The example: a large boarding facility with stabling for 700 horses in three stabling areas. On the facility, there were some private boarders as well as horses affiliated with 21 horse trainers.

Routine Biosecurity Measures

- **Stabling:** There were designated separate stabling areas for each trainers' horses. Each trainer attempted to house horses by risk-level group (i.e., young horses in training, schooling horses, and show horses that travel). Each group is typically handled in order of risk.
- **Feeding and cleaning equipment:** There were color-coded feed buckets, water buckets, muck buckets, and rakes for each designated trainer/area. The color coding was either with tape applied to the items or with use of different colored items (i.e., buckets, rakes). The color coding was a visual deterrent to help prevent accidental sharing of equipment.
- **Grooming equipment:** There were some color-coded or labeled individual pieces of grooming equipment in the tack room or on the stall door for each horse. Some equipment was shared and was cleaned and disinfected between use.
- **Routine health monitoring:** Some trainers maintained daily logs for horse temperature and treatment.
- **Personnel:** Some stabling areas had dedicated personnel to handle each group of trainers' horses. If that was not possible, frequent use of hand sanitizer and cleaning of boots was recommended.

Disease Outbreak–Enhanced Biosecurity Measures

An EHM case was confirmed in one stabling area on the premises and enhanced biosecurity measures were required to control the disease. Ensuring horse health and business continuity were critical to all trainers on the property. The intent of this sec-



Fig. 1. Restricted access in stabling area.

tion is to provide insight on the type of enhanced measures implemented during a disease outbreak.

- **Restricted access in stabling area:** A physical barrier separation prevented access of people and additional biosecurity signage was posted with restrictions (Fig. 1).
- **Restricted entry of horses:** Initially, horses were not allowed entry into the affected stabling areas on the premises. However, horses could enter stabling areas with no known infection. Horses were required to remain in their designated stalls and to request permission to change stalls (Fig. 2).
- **Designating exercise areas:** Restricted exercise of horses in affected barns to designated areas with limitations on the number of horses in the exercise areas at one time.
- **Restricted human access:** Access to the affected stabling area was restricted to personnel directly responsible for the care and training of the horses in that stabling area (Fig. 3). Individuals were not permitted to



Fig. 2. Restricted entry of horses.



Fig. 3. Restricted human-access area.



Fig. 5. Cleaning and disinfectant equipment.

move between stabling areas. Checkpoints were set up to log personnel movement in and of the affected stabling area. All personnel entering and exiting were required to use foot baths, disinfectant spray, and hand sanitizer.

- *Restricted dog access:* No dogs were permitted in the horse-stabling areas. Dogs on the premises were restricted to paved parking lot areas.
- *Monitored horse health:* Temperature monitoring of all horses was required two times each day. The temperatures were noted on the temperature logs posted on each stall door. Personnel monitored temperature logs daily to ensure that horse temperatures were being recorded. Elevations in horse temperatures were discussed with the attending practitioner.
- *Sick horse isolation:* Any horse with a temperature at or above 102°F and any horse displaying neurologic signs was immediately moved to a temporary isolation stabling area set up in a parking lot (Fig. 4). The perimeter of the isolation area was fenced off and only designated personnel dressed in disposable



Fig. 4. Sick-horse isolation.

coveralls, disposable boots, and gloves were permitted to enter the isolation area.

- *Strict cleaning and disinfecting protocols implemented:* (Fig. 5) Thorough cleaning and disinfection of equipment, stalls, trailers, and vehicles were required to ensure disease containment at the time a suspect or confirmed test positive exposed horse was identified. Tack, bridles, grooming equipment, and bandages were also exposed to direct sunlight to reduce risk of virus survival.
- *Re-routing, cleaning, and disinfection of vehicles:* All feed, hay, shavings, and manure trucks were rerouted to prevent disease transmission from high-risk stabling areas to low-risk stabling areas. To contain the virus, trucks were cleaned and disinfected between stabling areas.
- *Access of vendor trucks:* Local vendors who were aware of the situation were reluctant to enter the premises. Delivery protocols to clean and disinfect trucks upon entry and exit were implemented. Vendor personnel would also use disposable coveralls and disposable footwear covers when delivering supplies (i.e., grain, hay, supplements, bedding).
- *Equine service providers:* Protocols were implemented to permit service providers such as farriers to enter the premises. The farrier appointments were made for the end of the farrier workday, so the affected facility was the last stop for the farrier. Farrier parking was restricted to the premises perimeter. Work was done in the stabling area, with cleaning and disinfecting of all equipment between horses and with the farrier required to change clothes between horses. Disposable coveralls and boots were made available for service providers.
- *Biosecurity oversight:* Trained personnel were designated to continually walk through

Table 1. Biosecurity Supplies and Sources for Products

Product Name/Type	Potential Source	Contact Info	Approximate Cost
Plastic aprons	Grainger	(800) 472-4643 www.grainger.com	\$199.20 per package of 100
Tyvek coverall with attached hood, elastic wrists, and ankles	Enviro Safety Products, Valencia, CA 91355	Phone: (800) 637-6606 Fax: (559) 746-0317	\$114.99 per package of 25
White disposable gowns	eSafety Supplies, City of Industry, CA 91746	www.ensafesafetyproducts.com (877) 693-3754 (626) 369-1280	\$28/60 per package of 50
Disposable plastic boots ("Knot-a-Boot")	QC Supply, Schuyler, NE 68661	www.esafetysupplies.com (800) 433-6340 (402) 352-3167	\$14.99 per box of 50
Virkon-S: use spray bottle for disinfection of soles of boots/shoes	Valley Vet, Marysville, KS 66508	www.qcsupply.com (800) 419-9524 Fax: (800) 446-5597 www.valleyvet.com	\$70.95 per 10-lb container
Alcohol hand sanitizer: use product with at least 61% alcohol	Multiple sources. Examples include Purell and 3M Avagard	www.purell.com www.3m.com	Purell: ~\$1 per 2-oz bottle; 3M Avagard: \$13.50 per 16-oz bottle
Single-use thermometer probe covers	Valley Vet, Marysville, KS 66508	(800) 419-9524 Fax: (800) 446-5597 www.valleyvet.com	\$2.49 per package of 30
Water and feed buckets	Valley Vet, Marysville, KS 66508	(800) 419-9524 Fax: (800) 446-5597 www.valleyvet.com	~\$4.49 per bucket
Disinfectable Halter and Lead	Valley Vet, Marysville, KS 66508	(800) 419-9524 Fax: (800) 446-5597 www.valleyvet.com	\$19.95 for halter and \$7.49 for lead
Disinfectable Grooming Brush Set	Valley Vet, Marysville, KS 66508	(800) 419-9524 Fax: (800) 446-5597 www.valleyvet.com	\$6.95 per brush set

the premises to evaluate compliance with biosecurity measures. Failures in biosecurity were identified and immediately addressed.

5. Biosecurity Resources and Supplies

The American Association of Equine Practitioners (AAEP), the U.S. Equestrian Federation, and the American Quarter Horse Association are encouraging the equine industry to work with their veterinarians to implement biosecurity plans. Historically, biosecurity assessments and plans focused primarily on equine veterinary hospitals. Practitioners are now being asked to develop biosecurity plans for venues and large equine facilities. What biosecurity resources are available for the veterinary practitioner? The AAEP Web site has biosecurity resources that are reviewed at least annually and updated as needed based on new information and lessons learned. Under the Infectious Disease Control Guidelines, there are specific biosecurity guidelines, which address the risks and biosecurity measures discussed in the previous section. Ideally, routine and enhanced biosecurity protocols documents are put in place before a disease outbreak given that these are difficult to produce in a timely manner when other disease control issues take priority.

Isolation of a sick horse is the most important immediate action necessary during a disease outbreak. It is essential to identify potential areas for isolation of a sick horse in an area away from the remainder of the equine population. Most equine boarding facilities lack appropriate isolation stabling and may require construction of a temporary pipe coral isolation pen in a parking lot. Identification of a source for pipe corral fencing is essential. Isolation of a sick horse may require off-site isolation stabling. Advance sourcing of such appropriate alternate stabling in your area will allow for rapid isolation of a sick horse and decrease potential disease transmission risks. Vacant horse stables, vacant livestock facilities, empty vacated supply sheds, or local fair county fairgrounds may be available for use in these situations. Contacting owners of such facilities in advance and maintaining a current available list of optional housing areas for isolation is recommended.

Large facilities should prepare in advance for setting up an isolation area. The Center for Equine Health at the University of California–Davis provides valuable guidance on this topic in a document titled, “*How to Set Up a Disease Isolation Unit at Farm or Horse Show*” (https://www.cdfa.ca.gov/ahfss/animal_health/pdfs/S.pdf).

Large facilities should have a biosecurity supply kit available for an emergency disease outbreak situation. The kit should include disposable gloves, disposable coveralls, disposable boot covers, and

possibly disposable head covering.⁸ The supply kit should include a disinfectable (or disposable) halter and lead rope, grooming equipment, water and feed buckets, and a thermometer for clinical high-risk horse(s). For barrier protection, the supply kit should include a foot bath container, appropriate disinfectant, a boot brush for cleaning soles for the boot, and trash bags. Table 1 provides a list of biosecurity supply kit supplies and potential sources.

6. Summary

The equine industry is recognizing the need to implement biosecurity measures, particularly at equine events and large boarding facilities. The future of equine practice includes the provision of services for disease risk assessments with recommendations for best management practices and implementation of biosecurity measures. Assessments and implementation of routine biosecurity measures will decrease the potential for disease incursion. Development of plans and identification of resources for enhancement of biosecurity in the event of disease incursion will facilitate the timely control of a disease incident.

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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Understanding How Your Ultrasound Machine Works

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Equine veterinarians use ultrasonography every day in their practice. Tremendous progress has been made in ultrasonographic technologies within the last couple of decades. This paper provides a basic review of the physics of ultrasonography, standard operating features on portable ultrasound machines, as well as transducer types and capabilities. Several artifacts that are confusing during ultrasonographic evaluations are described, and two examples of recent developments in ultrasonography are presented. Author's address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32611; e-mail: pozorm@ufl.edu. © 2017 AAEP.

1. Introduction

Sound is a type of acoustic energy produced by vibrating bodies and propagated by various transmission media in the form of sound waves.¹ These waves are longitudinal (plane) and have a sinusoidal shape as well as four generic properties: period, frequency, length, amplitude, and velocity. The human ear can detect sound waves with frequencies between 20 Hz (20 cycles per second) and 20 KHz (20,000 cycles per second).² Sound waves that have frequencies above 20 KHz are categorized as ultrasound waves, whereas waves that have frequencies below 20 Hz are categorized as infrasound waves. Wavelength is the distance traveled by sound within one cycle. This parameter is inversely proportional to frequency. The amplitude or height of the sound wave is correlated with the intensity of the signal. Strong or loud sound signals are created by sound waves of high amplitudes. Velocities vary depending on the density and compressibility of the medium through which the sound wave is traveling. Medical imaging uses ultrasound waves with fre-

quencies between 1 MHz (1 million cycles per second) and 20 MHz.³ These waves are produced by the piezoelectric effect (from the Greek, *piezein*, to squeeze or press),⁴ namely the ability of certain non-conducting materials to generate an electric charge in response to applied mechanical stress (pressure-electric or squeeze-electric). Disk-shaped piezoelectric crystals (elements) change their volume and vibrate when an electric current is passing through them, which causes the media in front of them to deform and vibrate, thus producing ultrasound waves.⁵ In this way, electric energy is translated into mechanical energy. The same crystals are physically compressed by the incoming ultrasound wave (echo), which causes a voltage change on the electrodes as well as an electric impulse.

Four main modes of ultrasonography are used in veterinary medicine: A-mode, B-mode, M-mode, and D-mode. In A-mode, or amplitude mode, a single acoustic signal penetrates the evaluated tissues and returns as an echo displayed on the monitor as a horizontal waveform.² The amplitude changes in accordance with a degree of the acoustic mismatch of

NOTES

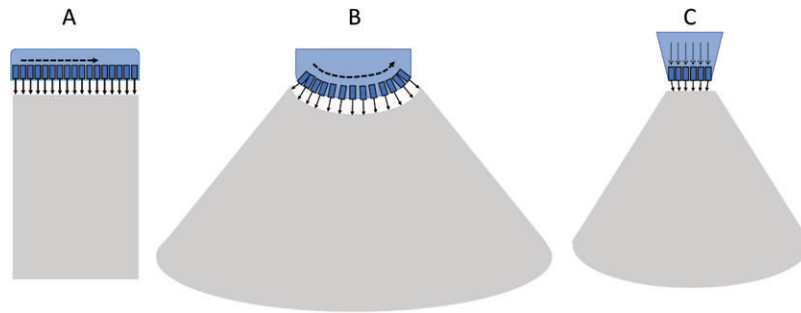


Fig. 1. Distribution of piezoelectric elements and direction of their activation in three different ultrasound transducers: (A) linear transducer; (B) curvilinear/convex transducer; (C) phase array transducer.

two media (tissues) at their interface, in various depths. This mode has rather limited applications and is occasionally used to detect fluid-filled structures such as the conceptus in pigs and small ruminants. The most frequently used mode of ultrasonography is B-mode, or brightness mode. A two-dimensional image consisting of a collection of dots (pixels) is displayed on the monitor. The brightness of each dot indicates the amplitude of the reflected (returning) wave, which is proportional to the difference in the acoustic impedance of the two materials (media).¹ M-mode, or motion mode, allows us to visualize the movement of the selected objects graphically. Numeric measures can then be objectively derived from this graph, such as heart rate. Finally, D-mode, or Doppler mode, uses the Doppler phenomenon to display blood vessels in colors (red and blue) of various intensity correlated with blood flow velocity. To obtain accurate measures of blood flow velocities and indices of tissue perfusion, spectral Doppler or pulse-wave Doppler modality needs to be available as well.

2. Equipment

A large variety of stationary and portable machines can be used for various applications in equine practice. However, portable units are more commonly used in equine reproduction, given that mares are often examined in the barn in field conditions. Battery-operated units can be used in places where electricity is unavailable. The majority of ultrasound machines have several modalities that can be activated when needed: B-mode (basic, most often used), M-mode (usually present in a basic version), and D-mode (usually optional). The “best” ultrasound machine for equine practice is dependent on a number of considerations. Each veterinarian must recognize his/her own needs, priorities, and applications to identify the most suitable machine for these particular uses. Some machines are simple to use and have numerous pre-programmed settings but lack manual setting options. Although these machines are user friendly, they do not allow for customized/sophisticated settings or advanced image processing. Other machines have many options, manual settings, and post-processing packages but

are more difficult to operate, which could be a problem for less advanced operators, especially in field conditions.

The main part of the ultrasound machine is the transducer, which emits ultrasound waves to tissues and receives a returning echo. The two basic types of transducers are mechanical and electronic.² In mechanical transducers, one or more crystals rotate or oscillate. These constantly moving objects tend to wear faster than the elements in electronic transducers. Hence, mechanical transducers are rarely used. Electronic transducers, by contrast, are more popular and provide a better-quality image. In array transducers, up to several hundred elements are arranged in a linear (linear transducer) or curved fashion (curvilinear or convex transducer) and connected to a multichannel transmitter/receiver (Fig. 1, A and B). A subset of elements is “fired” at once to form a single beam (single line). The next subset is “fired” immediately after the first one and so on. In this way, the entire area of interest is consistently swept from one side to another to form a two-dimensional image, which is changing in “real time.” The shape, direction, and location of the ultrasound beam can be controlled electronically without using mechanical parts. By contrast, in phase array transducers, all the elements are “fired” at all times, and the beam is steered electronically in different directions to sweep the entire area of interest (Fig. 1C).⁵ Linear transducers (probes), which produce rectangular images, are most commonly used for transrectal examinations of the reproductive tract of mares and stallions (Fig. 1A). During these examinations, the linear transducer is placed almost directly on the region of interest such as a mare’s ovary or uterus to visualize the fine details of its structure. It then generates ultrasound waves of high frequency (5 to 10 MHz on average). Although these waves generate images of high axial resolution, they are attenuated quickly and thus do not penetrate deeply. Sector transducers (curvilinear/convex or phase array) produce fan or pie-shaped images that offer a broad view of structures from a small area of contact (Fig. 1, B and C). These transducers are most often

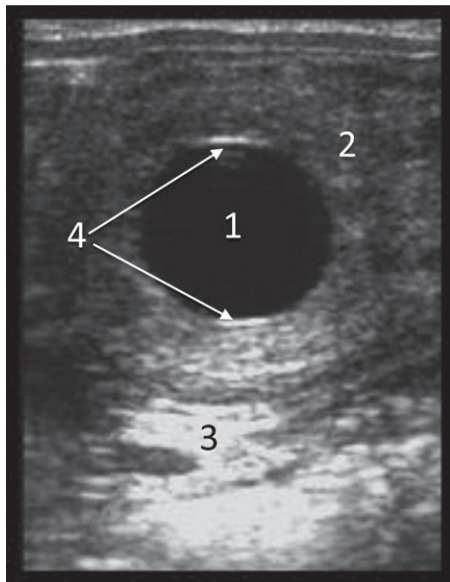


Fig. 2. Ultrasonographic image of early equine pregnancy (14 days): (1) hypoechoic embryonic vesicle; (2) uniformly echogenic uterine wall; (3) enhancement of echo below the embryonic vesicle (artifact); (4) specular echoes (artifact).

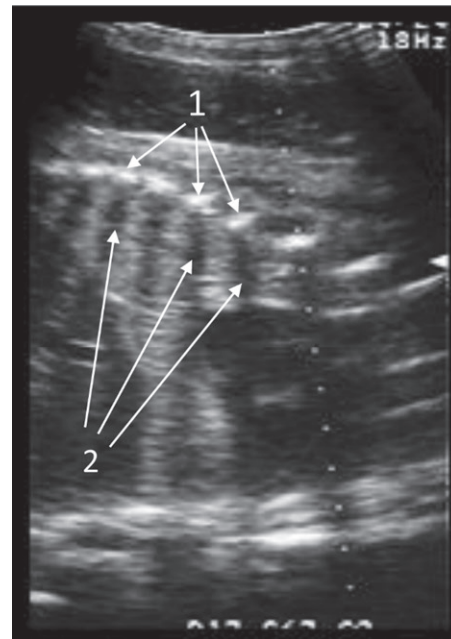


Fig. 3. Ultrasonographic image of the fetal chest in late pregnancy: (1) images of the fetal ribs; (2) shadowing generated by the fetal ribs.

used to evaluate late pregnant mares, with a focus on the fetal and placental structures. They must generate ultrasound waves of low frequencies (2 to 4 MHz on average) that penetrate deeply, even up to 35 mm. The tradeoff of such deep penetration is a low-resolution image. Smaller curvilinear transducers (micro-convex) are occasionally used in equine reproduction for the evaluation of the scrotal contents in the stallion or the mare's reproductive tract (small "finger transducer").

The main role of the console of the ultrasound machine is initiating, receiving, and processing ultrasound signals. The electric signal is amplified and converted by an analog or digital converter into a two-dimensional image that consists of numerous pixels or dots. The brightness of this grayscale image depends on the amplitude of the returning signal (echo).⁵

Dense tissues are strong reflectors and create a bright image; on the contrary, less dense tissues are weaker reflectors and the resulting image is darker. Structures filled with clear fluid do not create any echo; these are called anechoic, echolucent, or nonechogenic. They appear on the screen as black. The best examples of these structures are ovarian follicles or early embryonic vesicles (Fig. 2). All other images are echogenic and consistent with denser tissues, which send an echo of the ultrasound waves back to the transducer. They appear as a collection of pixels in different grades of gray. Very dense tissues will appear almost white (hyperechoic) and tissues with low density will show as very dark (hypoechoic). Some tissues cannot be penetrated by ultrasound waves and their structures cannot be

visualized given that the entire pulse is reflected back to the transducer. Good examples of these tissues are bones (Fig. 3).

3. Optimizing Ultrasound Images

Simple ultrasound machines have only a few knobs and buttons or keys on the consoles that allow for basic adjustments of monitor brightness, signal gain, image depth, freezing and saving images, as well as taking measures of various objects. Other machines have more elaborated consoles with numerous knobs for manual settings. Regardless of a type of the machine, monitor brightness should be adjusted first before any other settings are changed. This should start from setting brightness to its highest level, followed by turning brightness down gradually until the darkest level on the gray scale bar becomes black. The next step of setting up the ultrasound machine is adjusting gain. There is no specific way of doing it correctly, each ultrasonographer adjusts it to his/her liking. Increasing gain results in processing of more incoming echoes by the ultrasound machine, thus producing overall brighter images.⁶ There is usually one knob to decrease or increase an overall gain, as well as two or more knobs to adjust nearfield and farfield gain separately. Many machines have time gain compensation system with five to 10 sliding knobs, similar to an equalizer on a stereo, which allows for very subtle adjustment of gain in specific areas/layers of the image. It is recommended that the top (nearfield) knob is set off center to the left, with next knobs gradually moved toward the center and then off center to the

right. In contrast with the nearfield, the farfield needs high gain due to attenuation of the signal at higher depth.⁷ Unexperienced ultrasonographers have a tendency to use too high gain, which leads to loss of contrast and fine details on the image, as well as to increased production of noise and artifacts. Depth of the image is often changed several times during each examination. Too shallow depth is not recommended. An area of interest should be visualized at approximately 3/4 depth of the screen, with enough space for useful artifacts (shadowing or enhancement), just below this area. Many ultrasound machines have an option to manually control location of the focal zones, dynamic range, and gray maps. It is important to make sure that an area of interest is within the focal zone, which provides the greatest lateral resolution of the image.⁶ This can be obtained by adjusting depth of the image or changing position of the focal zone. Many machines have an option to add one, two, or more focal zones. However, this results in decreased frame rate and “jerky” flow of images on the screen. Another important parameter, which is essential in achieving desired quality of the ultrasound images, is dynamic range. High value of dynamic range is consistent with a wide range of shades of gray and overall smooth image. Low value of dynamic range means that there is a low range of shades of gray, which appears as a higher contrast on the image. Dynamic range is often called “compression.” The last of the most common adjustments of the ultrasound image is a gray map, which determines brightness of each shade of gray on the image.

4. Artifacts

The interpretation of ultrasound images is relatively easy for an inexperienced ultrasonographer; however, many artifacts, or the artificial results of imaging technology, can be misleading.⁸ Therefore, a basic knowledge of the most commonly occurring artifacts on ultrasound images is necessary for practicing veterinarians.

Initially, a specular echo in early equine embryos was interpreted as an embryonic disk, and only much later this misinterpretation was discovered⁹ (Fig. 2). This artifact occurs when a beam strikes a smooth surface, wider than the beam, parallel to the transducer.⁸ A small part of the beam is reflected back to the transducer, producing a strong echo, while the rest travels through the tissue (fluid in the ovarian follicle, uterine cyst, or embryonic vesicle) and strikes another reflecting surface at the bottom of the structure. In this way, two specular echoes are produced as bright straight lines.

Shadowing effects are often seen on ultrasound images (Fig. 3). These are produced either by the complete blockage of the ultrasound signal, or by its deviation (reflection or refraction). This phenomenon occurs when there is a significant difference in the acoustic impedance of two media at their interface. The acoustic impedance (z) of different tissues depends on their density (ρ) and compressibility or stiffness (k):

$z = \sqrt{(\rho \cdot k)}$.¹ Bones are good examples of materials with high impedance whereas air has very low impedance. Therefore, there is little or no transmission of the ultrasound wave through the soft tissue/air or soft tissue/bone interfaces. Almost entire ultrasound signal is reflected back to the transducer, and a shadow is created just below the interface of the two media.¹ A shadow is also produced as a result of reflection of the ultrasound beam to the surrounding tissue by a spherical structure such as the ovarian follicle.⁶ Part of this beam is often refracted into a fluid-filled structure, contributing to shadow formation as well. If the signal travels through the anechoic structure, such as an embryonic vesicle or an ovarian follicle, it is not subjected to attenuation like the signals traveling through echogenic tissues. Therefore, an echo coming from underneath the early embryonic vesicle is stronger (i.e., it has a higher amplitude) than that from other tissues (uterine wall) on both sides (Fig. 2).^{8,9} Although many other artifacts can be difficult to interpret, the above-described effects are commonly seen during the reproductive examination of the mare.

5. New Developments

In the past decade, new technologies such as harmonic and spatial compound imaging have been introduced to eliminate artifacts, decrease the “clutter” in near surface tissues, and reduce the “noise” level.³ There are two components in harmonic imaging: the first harmonic (original frequency wave) and the second harmonic (a wave frequency that is twice the original). The returning signal is the combination of these two signals that forms one “distorted” wave. The ultrasound system processes each component separately, which provides more information than regular imaging. In spatial compound imaging, the beam is steered in various directions, thus scanning the same area multiple times. The echoes from these different directions are compounded together into a single image. In this way, the image is less “grainy,” and has higher resolution and fewer speckles.

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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Ultrasound Evaluation of the Reproductive Tract in Mares: Why Ultrasonography is an Essential Component of Daily Practice

Malgorzata A. Pozor, DVM, PhD, DACT

The ultrasound evaluation of the reproductive tract of the mare has become an integral part of a routine reproductive evaluation. Ultrasonography is used for daily evaluations prior to and after breeding, as well as for assessment of pregnant and postpartum mare. This paper describes the common ultrasonographic findings in equine reproduction. Author's address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, University of Florida, Gainesville, FL 32611; e-mail: pozorm@ufl.edu. © 2017 AAEP.

1. Introduction

Ultrasonography not only adds to the findings gathered by other methods of clinical evaluation, but also provides valuable information that an equine practitioner cannot obtain in any other way. Therefore, it is imperative that all equine veterinarians that work in reproduction equip themselves with an ultrasound machine for everyday use. Having said that, ultrasonography cannot replace skilled manual palpation of all the structures of the reproductive tract. The complete manual palpation "per rectum" of the ovaries, uterine horns, uterine body, and the cervix has to be performed before the ultrasound examination. The ideal setting for this procedure is proper restraint of the mare in stocks, preventing the operator from injury due to kicks. Even with the mare restrained in stocks, caution still has to be taken since some mares tend to "sit" during examination, which can injure the operator's arm. If stocks are not available, a mare is positioned at the door of the box stall, with her hind legs

slightly outside the stall door. The door frame partially restrains the mare's movement and the operator stands beside the mare's hip while palpating. A twitch can occasionally be used to further immobilize the mare. Light tranquilization is applied if necessary; however, one should keep in mind that tranquilization will affect the uterine tone. Prior to ultrasonography, the mare's rectum has to be completely evacuated of fecal material using a copious amount of lubricant; the lubricant also must be used to allow the penetration of the ultrasound beam. A thorough palpation of all the structures of the reproductive tract is always performed before the ultrasound evaluation. After localizing all the structures of the reproductive tract and assessing their size and texture as well as the presence of normal and abnormal structures, the probe is introduced into the rectum. The transducer must always be covered dorsally by the examiner's hand and moved slowly to avoid traumatizing rectal mucosa or causing rectal tear. The examiner moves his/her hand with the transducer from one structure to another

NOTES

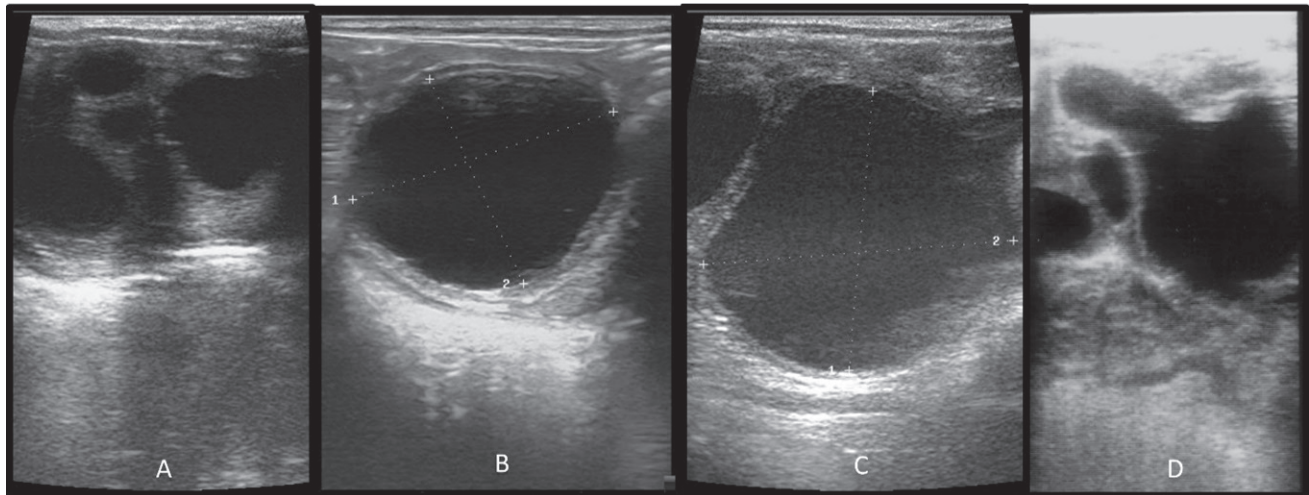


Fig. 1. Ultrasonographic images of the ovarian follicles in mares: (A) multiple, small follicles; (B) dominant follicle; (C) large dominant follicle; (D) pre-ovulatory follicle.

slowly and smoothly, making sure that the entire reproductive tract is continuously and consistently scanned. A thorough exam is particularly important during pregnancy diagnosis when the entire uterus has to be visualized to find a mobile embryonic vesicle and diagnose early twin pregnancy. During the ultrasound evaluation of the uterus, the transducer is usually held in a position parallel to the long axis of the animal. Given that the equine uterus is T- or Y-shaped, the image of the longitudinal section of the cervix and uterine body is visualized. The uterine horns are visualized in the form of a series of cross sections, whereas the ovaries are visualized from the medial side when the probe is slightly turned sideways.

2. Physiological Changes in the Reproductive Tract of the Mare

The ovaries are dynamic organs that undergo cyclic changes during estrous cycles. Active ovaries contain follicles of different sizes. Multiple small follicles may be present on one or both ovaries, one or two dominant follicles are found during estrus, and some large mid-cycle follicles can be found during diestrus. Subordinate follicles regress during the follicular phase. Several days before ovulation, a dominant follicle reaches a size of approximately 25 mm. It appears as a fluid-filled anechoic structure that consistently increases its size until ovulation. The average growth of the pre-ovulatory follicle is 3 mm per day,^{1,2} until 1 to 2 days before ovulation when the follicle rarely increases its size any further. Occasionally, a slight decrease in size may be observed on the day of ovulation. The ovulating follicles in the mare are broad in size (20 to 70 mm); however, the majority of light breed mares ovulate when their follicles reach a diameter between 40 and 45 mm (rarely when their diameter is less than 35 mm).²⁻⁵ Friesian mares grow larger follicles than

other breeds, reaching 52 mm at 48 hours prior to ovulation.⁶ Individual mares tend to ovulate the same size follicle from cycle to cycle.

Changes in follicular diameter and other characteristics can be accurately assessed by using ultrasonography (Fig. 1). The diameters of the ovarian follicles are obtained by using calipers to monitor their growth.⁷ In addition, changes in shape can be easily assessed. Pre-ovulatory follicles in the mare lose their round shape and become irregular, developing a “point” or “cone” toward the ovulation fossa and may have a slightly thickened follicular wall (Fig. 1, C and D). The shape changes due to a decline in antral fluid pressure shortly before ovulation.⁸ The avascular granulosa layer of the follicular wall becomes more echogenic in the pre-ovulatory follicles, whereas highly vascularized theca interna and externa appear as an anechoic band.^{9,10} Color Doppler signals are strong within the anechoic band, and their intensity increase daily as the follicle matures. However, an abrupt decrease in blood perfusion of the follicular wall occurs a few hours before ovulation, as shown using color Doppler ultrasonography.¹¹ The rectal palpation of pre-ovulatory follicles reveals a softening texture and increased sensitivity.

Ovulation in the mare may be abrupt (60 seconds), or gradual (6 to 7 minutes).² As a result, the follicular fluid is evacuated, but the follicular cavity may fill up with blood or a mixture of follicular fluid and blood soon afterward, forming a corpus hemorrhagicum (CH). Therefore, the actual collapse of the follicle is rarely observed during ultrasound examination. During the rectal palpation of the CH, a soft and sensitive indentation can be felt. In some instances, however, a follicle-like structure is felt, which is difficult to differentiate from the pre-ovulatory follicle without the aid of ultrasonography. The ultrasonographic images of the CH in

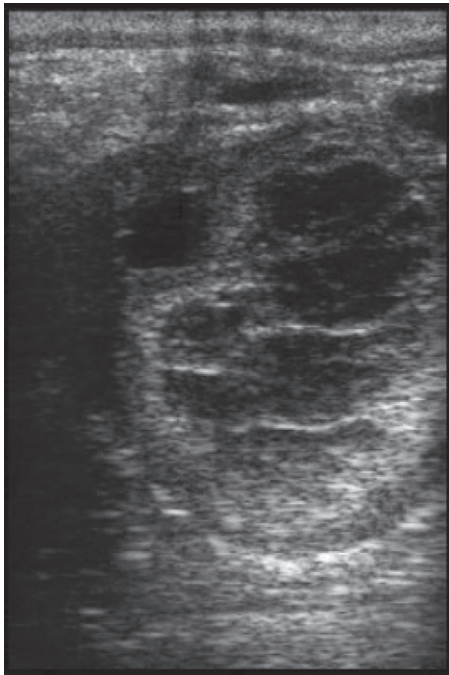


Fig. 2. Ultrasonographic image of CH.

mares are variable.⁷ The most typical ultrasonographic appearance of a fresh CH is spider web-like (blood clot), but it could also be uniformly echogenic (Fig. 2). A fresh CH may look almost like a follicle, but with numerous hyperechoic spots or bands. The luteinization of the ovulated follicle occurs (primary granulosa cells in the mare), the corpus luteum (CL) is formed, progesterone is secreted by the luteal cells, and a mare enters the luteal phase (diestrus).

The uterus undergoes changes concurrently with the ovarian activity. During estrus, ovarian folli-

cles produce large amounts of estrogen and a mare's uterus develops a pronounced edema of the endometrial folds (Fig. 3B). A uterus with estrous edema appears on the ultrasonographic image as an "orange slice" or "cartwheel." Occasionally, the examiner can see a small amount of anechoic intraluminal fluid, which is normal during estrus. The intensity of the uterine edema subsides approximately 24 hours before ovulation (Fig. 3C).

A mature CL in the mare cannot be detected by palpation. Ovulation occurs only in the ovulation fossa, and therefore the CL is completely buried within the ovary. However, the introduction of ultrasound has allowed the accurate detection of ovulation as well as of the development of the CH and CL (Fig. 4). The CL usually appears as a uniformly echogenic, even hyperechoic, roundish structure with or without a central cavity (Fig. 4, C and D). A blood clot in the center may persist throughout the entire luteal phase of the cycle or become progressively smaller to finally disappear. Progesterone concentrations are closely associated with the amount of luteal tissue, which can be objectively measured using ultrasonography. The cross-sectional area of the CL decreases progressively in mares during late diestrus in parallel to changes in progesterone concentrations.¹² These changes can also be observed subjectively during frequent ultrasound examinations. Furthermore, changes in vascularization of the CL can be evaluated using color Doppler ultrasonography. It was shown that a decline in the luteal blood flow during diestrus proceeds changes in concentration of progesterone, which can be useful in practice in early detection of failing CLs.¹³

Follicular growth is also observed during diestrus. Each follicular wave has one dominant follicle and a number of subordinate follicles.² The follicular wave occurring during estrus and producing an ovu-

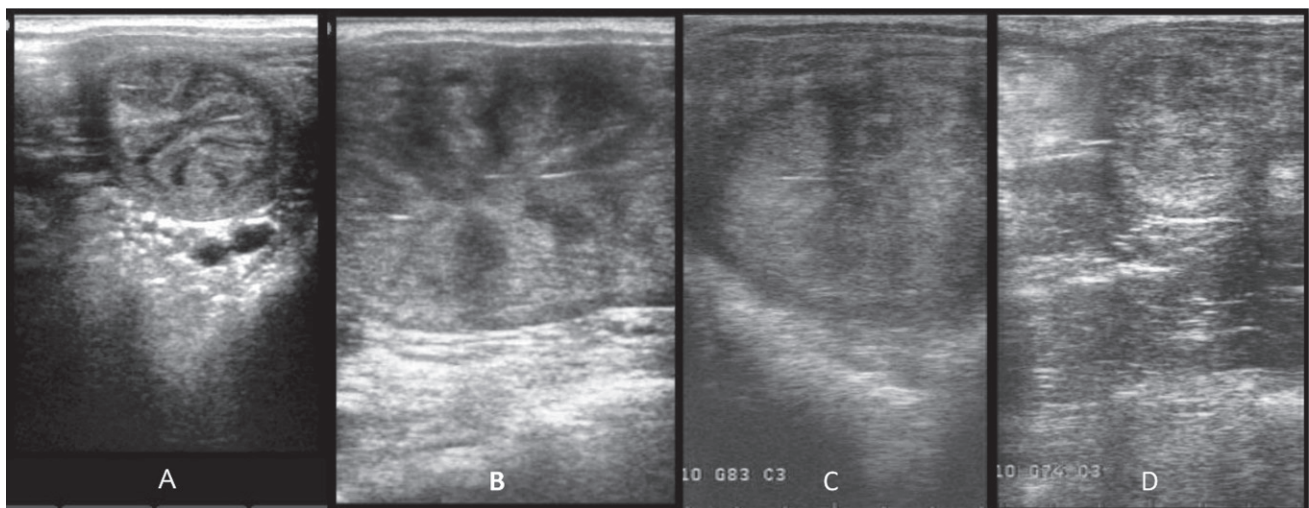


Fig. 3. Ultrasonographic images of equine uterus in different stages of the estrous cycle: (A) mild edema on the beginning of estrus; (B) pronounced edema in mid-estrus; (C) decreasing edema shortly before ovulation; (D) no edema during diestrus.

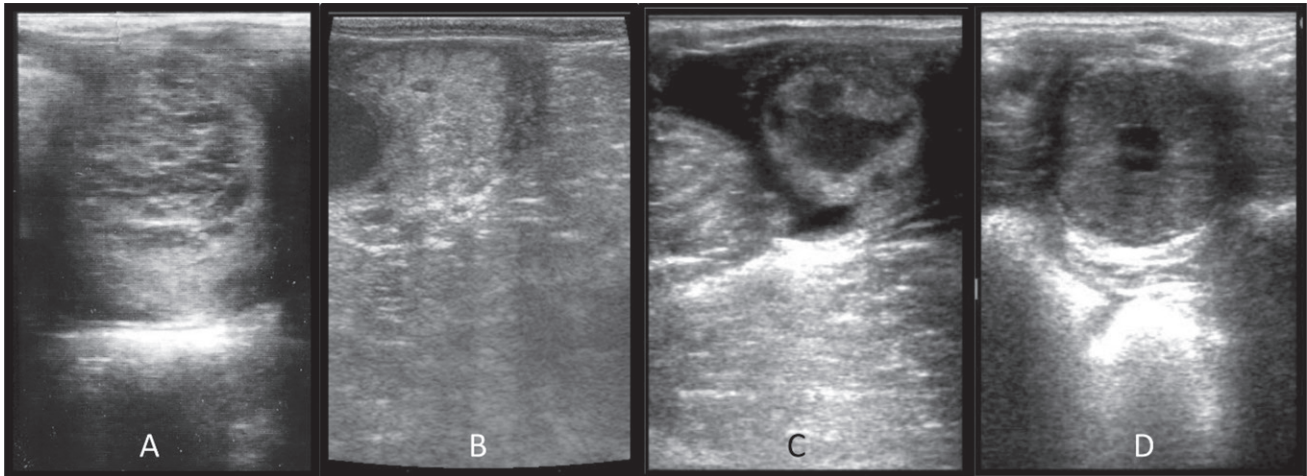


Fig. 4. Ultrasonographic images of corpora lutea: (A) fresh CL a spider-web appearance; (B) mature, uniformly echogenic CL; (C) mature CL with large, fluid filled cavity; (D) mature CL with small central cavity.

lating follicle is called the primary wave, and the next wave (during diestrus) is called the secondary wave. There are occasions when the secondary wave does not occur. The dominant follicle of the secondary wave may regress, ovulate, or even produce anovulatory follicles. Therefore, the detection of a large follicle, either by palpation or by using ultrasonography, is not evidence that the mare is in estrus. Other signs of heat must be found to confirm that the mare is ready to be bred (positive teasing by the stallion, uterine edema, and relaxed cervix). Breeding a mare that has a large follicle during diestrus is still a relatively common error and should be avoided. Additional follicular waves may also occur during diestrus in mares without producing a dominant follicle and these are called minor waves.

Progesterone production affects uterine tone and ultrasonographic appearance in the mare. The uterus becomes toned, the uterine edema disappears (Fig. 3D), and the cervix elongates and closes. A characteristic hyperechoic line is visible on the image of the longitudinal section of the uterine body, which is the effect of the interface of the uterine walls.⁷ No fluid should be visible in the uterine lumen at this stage of the cycle.

The above-described changes in equine ovaries and in the uterus, occur during the breeding season. Ovarian activity is less regular during the transitional period, which happens in the fall and spring.² In the fall, mares undergo a seasonal decrease in ovarian activity, which ends in an anestrous period. A similar situation happens in early spring when the length of daylight increases and a resurging phase occurs, followed by the transitional period; then, regular ovarian activity restarts. During early transition, mares' ovaries are significantly larger than during normal breeding season. This happens due to the large number of follicles, which

start developing rapidly (Fig. 5). At first, these follicles have a mean size smaller than 20 mm in diameter. Later in transition, some follicles grow to pre-ovulatory sizes (> 35 mm), whereas others regress. Some follicles may even grow to 60 to 70 mm in diameter. This emergence of new follicles and the regression of others occurs until one dominant follicle finally ovulates. It is difficult to assess when a transitional mare ovulates for the first time. Therefore, only the detection of the first ovulation in the season, by either using palpation with ultrasonography (detection of the CL) or measuring progesterone concentration (≥ 2 ng/mL), is proof that the mare is through the transitional period and has just entered the breeding season. During transition, the uterus has a variable texture on palpation and an echotexture on ultrasonographic images. Initially, it is often small and flaccid, but later develops a massive edema, which may be present for a

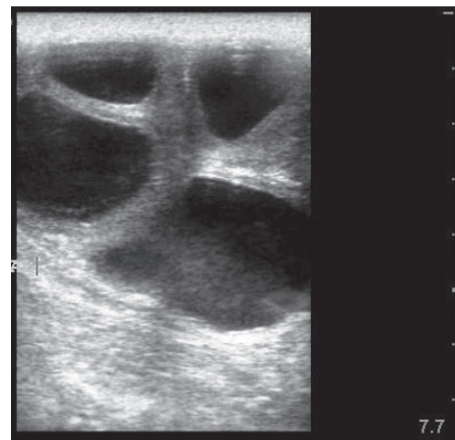


Fig. 5. Ultrasonographic image of the transitional ovary with multiple follicles.

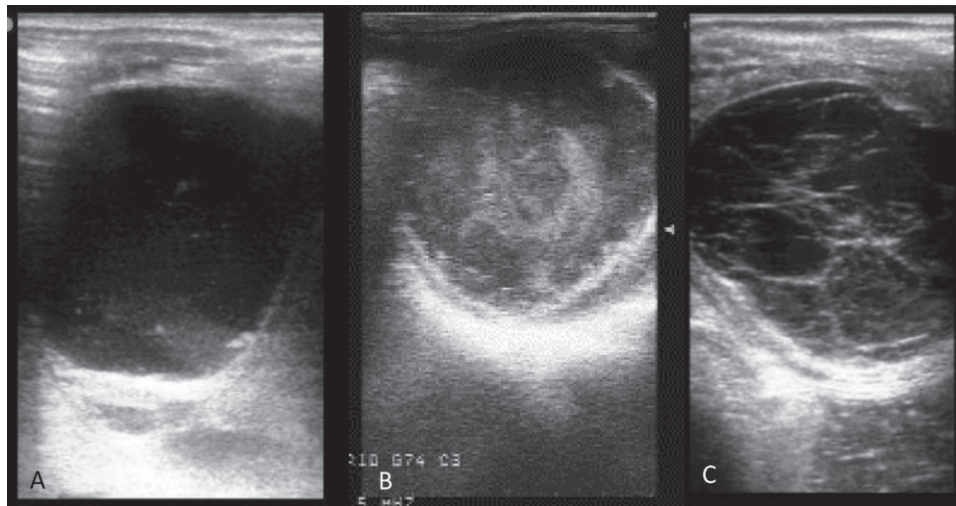


Fig. 6. Ultrasonographic images with anovulatory and anovulatory/hemorrhagic follicles: (A) large anovulatory follicle with snow-ball appearance; (B) anovulatory/hemorrhagic follicle, filled with blood; (C) anovulatory/hemorrhagic follicle with spider-web appearance due to formation of fibrin strands.

long time or come and go multiple times. The mare is under the influence of estrogens produced by multiple follicles, and no progesterone is produced by the CL. Therefore, mares usually show signs of estrus for a prolonged period of time.

In contrast with transitional periods, anestrus is a quiet time for the ovaries. During this phase, ovulations do not occur. In fact, anestrus is defined as extending from the last ovulation of the ovulatory season to the first ovulation of the subsequent ovulatory season.² It is a common belief that mares' ovaries are almost completely inactive during anestrus. However, the numbers and sizes of ovarian follicles may still change, except that none of them grow to the pre-ovulatory size. Ovarian follicles rarely exceed 10 to 15 mm in diameter during this stage of mares' reproductive cycle.² During anestrus, a mare's uterus is flaccid, does not have tone, and does not develop a uterine edema. In fact, the uterine wall is so thin that it may be difficult to palpate it rectally. In addition, it has an irregular appearance on the ultrasonographic image, being pressed by the abdominal contents. In contrast with the anestrous ovary, an inactive ovary hardly has any follicles at all and the ovaries are very small. This finding in sexually mature mares may be due to malnourishment or chromosomal abnormalities.

3. Abnormal Findings in the Reproductive Tract of the Mare

Ovarian Abnormalities

Anovulatory Follicles

Some dominant follicles continue their growth during estrus, become abnormally large, and do not ovulate (Fig. 6). They may even reach 60 to 100

mm in diameter. In contrast with transition, when this is a normal process, these events should not occur during the breeding season. Initially, anovulatory follicles have a normal texture and ultrasonographic appearance, indistinguishable from the normal ovulatory follicle. Later on, numerous hyperechoic reflections in the shape of small speckles or a spider web-like structure are seen in the anechoic fluid^{7,14} (Fig. 6). These reflections may correspond to bloody contents (as in the CH shortly after ovulation) or may represent the onset of luteinization. Anovulatory follicles often continue having hemorrhagic contents (hemorrhagic anovulatory follicles), which form a blood clot and do not significantly change their ultrasonographic appearance or size for a prolonged period of time (nonuniformly echogenic contents, numerous hyperechoic reflections that do not move during the ballottement of the follicle).¹⁵ Others slowly luteinize (without ovulation) and may look similar to the CL with a central cavity. The presence of anovulatory follicles may be frustrating for reproductive specialists, given that they rarely respond to treatment (i.e., human chorionic gonadotropin [hCG]), and spontaneously regress after 3 to 6 weeks. Secondary follicles may develop and ovulate despite the presence of anovulatory follicles, but this does not always happen. Therefore, mares that develop these structures should be monitored closely.

Ovarian Hematomas

Occasionally, hemorrhagic anovulatory follicles undergo a more dramatic course of events. Bleeding may continue via diapedesis into the follicular lumen, which expands considerably until it reaches a large size (100 to 300 mm). This expansion often leads to atrophic changes in the ovarian stroma and

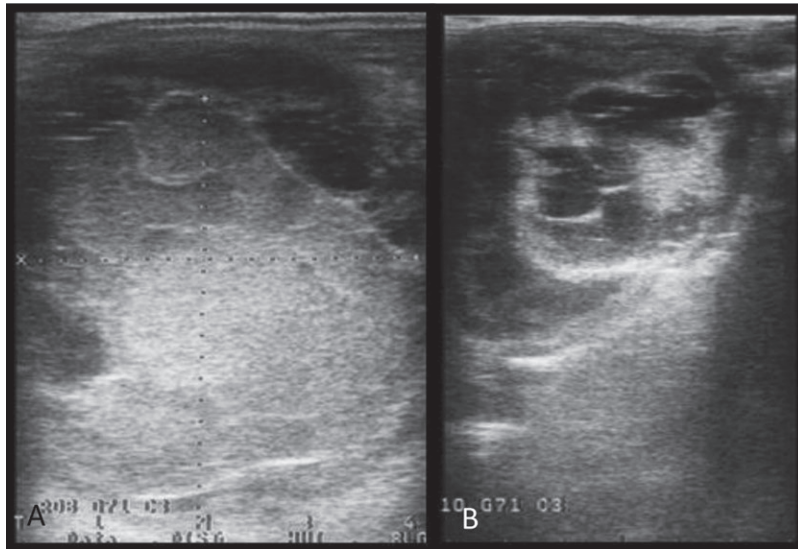


Fig. 7. Ultrasonographic images of ovarian hematomas: (A) large, organizing hematoma; (B) “old” hematoma that is decreasing in size.

the hemorrhagic follicles become ovarian hematomas (Fig. 7). These structures do not luteinize and initially appear similar to hemorrhagic follicles on the ultrasonographic image (a hypoechoic lumen with snow-like echoes), and are nonuniformly echogenic or hyperechoic once they start organizing (Fig. 7). Occasionally, ovarian hematomas may be painful, especially during rectal palpation. They resolve slowly, slower than anovulatory follicles.

Ovarian Tumors

Ovarian tumors occur relatively often in the mare, with granulosa cell tumors (GCTs) most commonly diagnosed (Fig. 8). Although the results of the ultrasound evaluation of the ovary with this tumor may be suggestive, it cannot be reliably diagnosed by ultrasound examination alone. Other diagnos-

tic methods must also be used. A GCT is derived from hormone-producing tissue, and therefore produces increased amounts of steroid hormones. Depending on the endocrine profile, the mare may exhibit a wide variety of behavioral symptoms: stallion-like behavior, nymphomania, anestrus, and increased aggression.¹⁶ This tumor has been diagnosed in mares of all ages and in various stages of their cycle, even in pregnant mares. However, it most often occurs in middle-aged, anestrous, barren mares. A GCT is usually benign and grows slowly, but it may reach a large size and affect the other abdominal organs (small colon obstruction, hemo-peritoneum, etc.). Rectal palpation reveals an enlarged, smooth ovary on one side and a small, inactive ovary on the other. The affected ovary has a completely obliterated ovulation fossa. The most characteristic ultrasonographic appearance of this mass is multicystic, but it may also be completely solid or have only one large fluid-filled cavity (Fig. 8). The walls separating the cystic structures are thicker than those between the follicles within normal ovaries or between cysts.

A definite diagnosis of a GCT is usually made based on the results of endocrine evaluation. High inhibin concentrations are produced by neoplastic cells and inhibit follicle stimulating hormone (FSH), which leads to the inactivity of the contralateral ovary. Inhibin serum concentration is considered to be positive for a GCT when it is ≥ 1 ng/mL and suspicious at levels of ≥ 0.7 ng/mL.¹⁷ Testosterone is often elevated, especially when stallion-like behavior is exhibited (> 100 pg/mL), and estrogens tend to be higher than in a normal cycling mare, especially when the mare exhibits nymphomania. More recently, the assessment of another hormone, anti-Müllerian hormone (AMH), has been validated as an additional diagnostic test for GCTs.¹⁷ This hormone is pro-

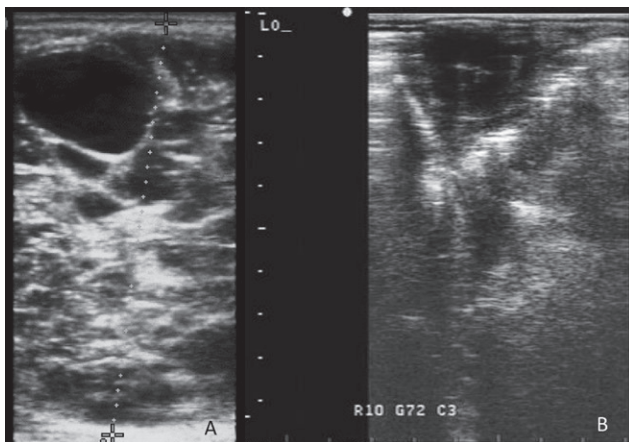


Fig. 8. Ultrasonographic images of ovaries from a mare that has GCT on one of her ovaries: (A) GCT; (B) atrophic contralateral ovary.

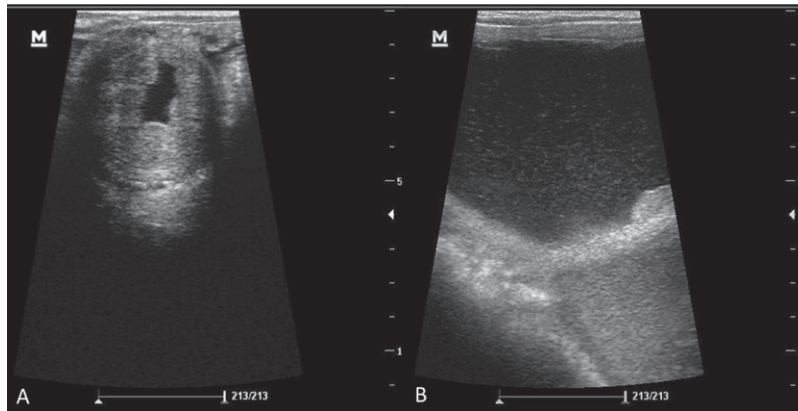


Fig. 9. Ultrasonographic images of uterine fluid: (A) uterus with small amount of fluid; (B) uterus with large amount of fluid.

duced by granulosa cells; its concentration is significantly elevated in mares with a GCT (> 4.2 ng/mL). Currently, the AMH assay is the most reliable marker of a GCT in mares because it has higher sensitivity (98%) than testosterone (48%), inhibin (80%), and testosterone and inhibin combined (84%).

Other ovarian tumors are seen rarely in mares. Among them, the most commonly diagnosed is the ovarian teratoma. This tumor is derived from pluripotential germ cells,¹⁸ is benign, and is nonsecretory. Given that it contains a mixture of various structures (cartilage, skin, bone, hair, nerves, sebaceous material, teeth, etc.), its ultrasonographic appearance is variable. However, it usually contains numerous fluid-filled cavities separated by variably echogenic or even hyperechoic (calcifications) walls. These chambers also have echogenic contents that are often shadowing due to the presence of bones and teeth.

The serous cystadenoma of a mare's ovary can be easily misdiagnosed as a cystic ovary. It develops from the epithelium of the various ovarian structures.¹⁸ It may produce testosterone, but a contralateral ovary usually functions normally and the mare's behavior is unaffected. On ultrasonography, this neoplastic mass appears as a collection of multiple fluid-filled structures separated by thin walls.

Periovarian and Fossa Cysts

Embryonic vestiges and cystic accessory structures associated with the ovary and oviduct are common in mares.¹⁹ They may have a similar appearance and texture to ovarian follicles, and therefore may be easily confused even when ultrasonography is used. In fact, it is easier to differentiate ovarian follicles from periovarian cysts during manual rectal palpation than using ultrasonography. Periovarian cysts are adjunct to the ovary, but are mobile, whereas the follicles are imbedded within the ovary. Furthermore, periovarian cysts do not change their sizes and echotexture during the estrous cycle as follicles do, and therefore a series of ultrasonographic evaluations is helpful for differentiation.

Periovarian cysts rarely affect a mare's fertility unless they are large. However, so-called fossa cysts may impede the release of the oocyte from the ovulation fossa and be detrimental to fertility. These are usually quite small (a few millimeters) and localized right at the ovulation fossa. Ultrasonography may be helpful for visualizing them, but they are often missed due to their small size.

Uterine Abnormalities

Abnormal Uterine Contents

The presence of intraluminal fluid in the uterus in the mare is not always abnormal. A very small amount of fluid may be present during estrus and the early postpartum period (Fig. 9A). However, the large accumulation of uterine fluid in a nonpregnant mare is always a sign of pathology and should be diagnosed and treated (Fig. 9B).

Uterine fluid, which appears during estrus in the mare, is usually anechoic and it disappears spontaneously without consequences. Increased echogenicity is consistent with increased cellularity and may be suggestive of an inflammatory process associated with an infection or transient inflammatory process shortly after breeding. Uterine infections require treatment, whereas normal nonsusceptible mares should recover from post-breeding endometritis without intervention. Some older, multiparous mares have problems with uterine clearance and these require specific treatment after breeding as well as the close monitoring of their uterine contents using ultrasonography. There should be no fluid in the uterus during diestrus. The presence of fluid in this stage of the cycle is usually associated with infection.

Small to moderate amounts of fluid are usually seen shortly after parturition. This fluid may be echogenic due to high cellularity. Hence, this should be cleared up spontaneously within a few days and before a foal heat. However, mares that have limited exercise and do not have suckling foals by their side may have problems with uterine clearance and require treatment. A large amount of

echogenic, foul-smelling fluid in the uterus of a postpartum mare is usually a sign of metritis, which is a life-threatening condition and should be promptly diagnosed and treated.

Some mares accumulate a large amount of fluid in the uterus (even 60 L) for prolonged periods of time and do not become sick. Depending on the characteristics of this fluid, this condition is called pyometra, mucometra, or urometra. Pyometra is often associated with the physical or functional obstruction of the cervix, which does not allow drainage. Mucometra may be a result of an imperforate hymen in fillies and the backflow of uterine secretions produced once puberty is reached. The ultrasonographic image of pyometra in the mare shows highly echogenic uterine contents and a stretched, thin uterine wall. Occasionally, the uterus is hanging far into the abdominal cavity, beyond the pelvic brim, and may be inaccessible from a transrectal approach. Therefore, transabdominal ultrasonography may be necessary for diagnosis. Once diagnosed, pyometra should be treated by draining through the cervix and/or hysterectomy. Opening the obliterated cervix may be challenging and this requires the application of force and/or surgical instruments. Partial drainage may be necessary for successful hysterectomy. Mucometra usually has less of an echogenic ultrasonographic appearance. An imperforate hymen may be manually ruptured to release fluid pressure, but a thickened, persistent hymen may need to be removed using simple surgical instruments. Urine is often accumulated in the uterus of mares with the cranioventral displacement of the vagina and uterus. Given that urine is echogenic, uterine content has a similar echotexture in the case of pyometra. Urine should be removed from the uterus and uterine contractions have to be induced/hastened using oxytocin treatment. The surgical repair of the anatomical defect preventing the further accumulation of urine in the uterus should also be considered (urethral extension).

Uterine Cysts

Uterine cysts are often confusing for equine practitioners during pregnancy diagnosis in mares. Their ultrasonographic appearance is similar to and often undistinguishable from an early embryonic vesicle⁷ (Fig. 10). They may be very small, medium-sized, or large; perfectly round, ovaloid, or irregular; single, multiple, or with multiple compartments; localized in one uterine horn, or disseminated throughout the entire uterus; luminal, transmural, or subserosal. Their contents are anechoic and their walls, similar to an early embryonic vesicle, often generate strong specular reflections.

Uterine cysts have an endometrial or lymphatic origin. Endometrial cysts are derived from the endometrial glands and are usually quite small (< 10 mm in diameter).²⁰ Lymphatic cysts come from the lymphatic system but are not always associated with dilated lymphatic lacunae in uterine biopsies.

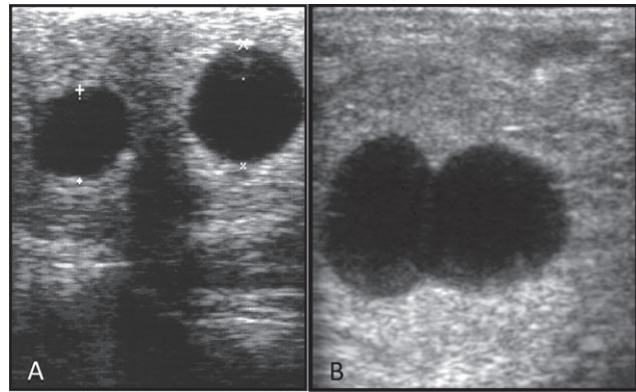


Fig. 10. Comparison of ultrasonographic image of early twins (A) and uterine cysts (B).

These cysts occur most often in older mares; they are usually larger than endometrial cysts and may reach 30 to 50 mm in diameter. Some cysts progressively increase in size, but not at a rate comparable with the embryonic vesicle. Therefore, the follow-up evaluation of an early pregnancy in the mare is usually diagnostic, given that an early embryonic vesicle changes its size, shape, and structures in a characteristic manner, whereas cysts do not. It is good practice to identify all uterine cysts in the mare's uterus before each breeding season to avoid confusion and errors such as misinterpreting a cyst as a twin embryo.

Cysts by themselves are rarely detrimental to fertility. Only large cysts can affect the mobility of an early embryo, which is necessary to signal pregnancy to the mare. Occasionally, the absorption of nutrients may be affected if the cyst is adjunct to the wall of the yolk sac or allantois.

Several treatments of large uterine cysts have been attempted with various degrees of success. Just rupturing or puncturing is ineffective (cysts will fill up again). Electrocoagulation or hysteroscopic (laser removal) seems to be a much more effective technique.²¹

Uterine Tumors

Uterine tumors are rare in mares. They are usually leiomyomas, which are slow growing and benign.²² These tumors are usually relatively small (5 to 15 cm in diameter), become necrotic, and cause uterine bleeding. Leiomyomas are palpable rectally as hard nodules or a distinct bulge of the uterus; however, their exact size and nonuniformly echogenic echo structure can be easily visualized by using ultrasonography.

Various Echogenic Reflectors⁷

Air appears as hyperechoic spots or lines due to large differences in the acoustic impedance generated by air and reproductive tissues (Fig. 11A). It is often seen in the uterine lumen shortly after breeding or other transvaginal manipulations such as taking a uterine

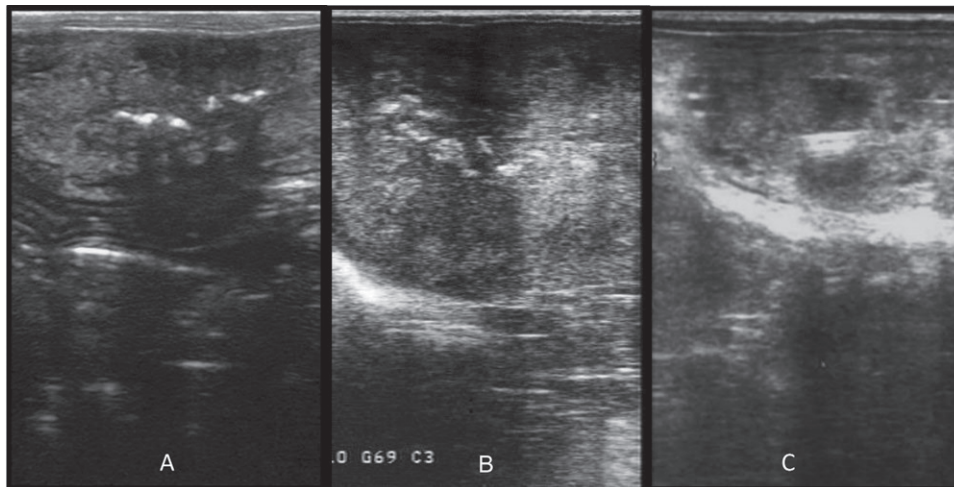


Fig. 11. Ultrasonographic images of uterine reflectors: (A) air bubbles in the uterus; (B) persistent uterine cups; (C) tip of the uterine swab broken off in the uterus.

swab for culture.²⁰ It may also be detected in the uterus of mares that have a poor vestibular-vaginal sphincter and develop pneumouterus.

Bone fragments completely block the penetration of the ultrasound waves and create shadow effects. If found in the uterus, they are usually remnants of the macerated fetus.²⁰ They remain in the uterus for prolonged periods of time, causing infertility, and are difficult to remove—long grasping instruments may be necessary.

Endometrial cups that form in the uterus of a pregnant mare between the 36th and 38th days of gestation^{23,24} have a limited life span of 50 to 90 days^{25,26} and disappear between the 100th and 120th days of gestation. If a mare loses her pregnancy after the 35th day of gestation, the endometrial cups are present in the uterus for the same period of time as if the mare was still pregnant, which affects her ability to cycle normally and become pregnant soon. Occasionally, the cups are present for a prolonged period of time (beyond the 120th day of the pregnancy). In such a case, they are called persistent endometrial cups.²² These are usually degenerating, calcified structures that appear on the ultrasonographic image as bright (hyperechoic) comma-shaped structures located around the base of the formerly pregnant horn (Fig. 11B). They are difficult to terminate. Some success in removing them has been reported by using hysteroscopic laser procedures.

Foreign bodies are occasionally found in the mare's uterus. The tips of uterine swabs may be lost during the swabbing procedure²² (Fig. 11C). These may cause massive inflammation, which affects ovarian function and fertility.^{27,28} After localizing a foreign body by using ultrasonography (swab has hyperechoic appearance), it should be removed manually, or, if this is not possible, by using hysteroscopy and grasping instruments.

4. Equine Pregnancy

Ultrasonographic Diagnosis of Pregnancy⁷

The introduction of ultrasonography to equine practice revolutionized the approach to the diagnosis, monitoring, and management of equine pregnancy. The reliable detection of equine pregnancy by palpation “per rectum” is possible by approximately the 28th day of gestation, when a distinct bulge is detectable at the base of one of the uterine horns. At that time, the nonpregnant mare has already passed a deadline for her second breeding, given that the interovulatory period in the mare is approximately 21 days. Therefore, the ability to reliably diagnose pregnancy by day 14 using ultrasonography is a great asset for the equine breeder (Fig. 12).

An equine embryo descends to the uterus by days 5 to 6 after ovulation. However, it is too small to be visualized, even when using sophisticated ultrasound equipment. It may become visible at day 9 as a small fluid-filled vesicle in any area of the uterus (horns and body)²¹ (Fig. 12). It is growing in size, retaining its distinct spherical shape up to days 16 to 17 post-ovulation, after which the shape of the embryonic vesicle starts changing. The early embryonic vesicle is mobile in the uterine lumen through days 16 to 17 post-ovulation,²¹ which is necessary for pregnancy recognition and the prevention of early luteolysis. Smaller (younger) embryos spend more time in the body than in the horns,²⁹ probably due to their small size. The ultrasonographic image of an early spherical equine embryonic vesicle has the characteristic specular echoes on the dorsal and ventral poles, is contained in the uniformly echogenic thick circle of the uterine wall, and has anechoic contents (yolk sac).⁷ The ventral uterine wall appears hyperechoic due to an echo

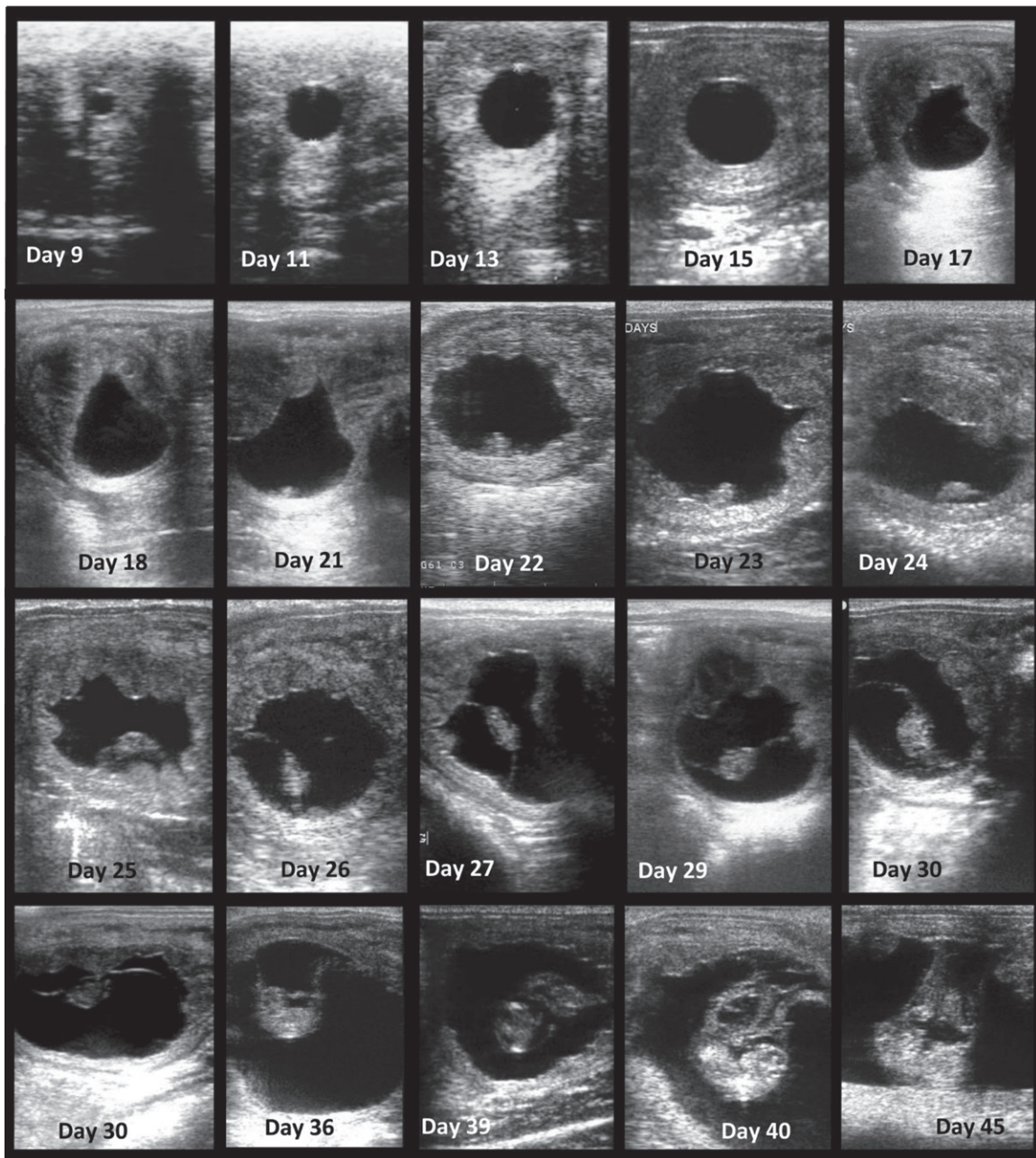


Fig. 12. Ultrasonographic images of equine pregnancy in various stages of development.

enhancement (artifact), and two lines of shadows are seen on both sides below the vesicle (artifacts).

Most equine practitioners choose day 14 for an initial pregnancy diagnosis because it is reliable at this time, but also because this is the optimal time for diagnosing and managing twins. The embryonic vesicle starts changing shape by days 16 to 18 from round to triangular (“guitar-pick shaped”) (Fig. 12). The vesicle becomes less turgid and the uterine wall becomes thinner on the ventral side. The ventral side of the uterine wall and embryonic vesicle remain roundish, whereas the dorsal side may appear thicker and irregular. The embryo proper

can be detected by days 20 to 21 as a small protrusion on the ventral aspect of the vesicle, but the heart beat is not seen before days 24 to 25 (it may be visualized earlier with ultrasound machines with superior resolution). Simultaneously, the allantoic cavity starts to fill up with fluid and is readily visible at the bottom of the vesicle. The embryo is lifted up and suspended between the shrinking yolk sac and expanding allantoic cavity. This process provides useful yardsticks for estimating the age of the early pregnancy in the horse. At day 27, the allantoic cavity takes approximately one third of the embryonic vesicle, whereas by day 30, it occupies half of the

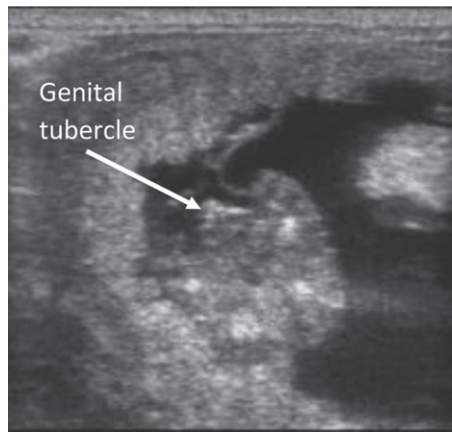


Fig. 13. Ultrasonographic image of the genital tubercle in the fetus at 65th day of gestation.

vesicle already, with the embryo suspended in the center. The embryo is pushed up into the upper third part of the vesicle by day 33 and almost all the way up at the dorsal pole by day 35. A small remnant of the yolk sac is still seen by the dorsal pole, but this disappears completely by day 40 when the umbilical cord is fully formed. From that time, the conceptus is no longer called an embryo but a fetus and it starts “sinking” down toward the ventral side again.^{2,30} This “migration” to the bottom is completed by approximately day 45 of gestation.

Ultrasonographic Monitoring of Equine Pregnancy

The fetus and fetal membranes continue to develop during gestation, and the uterus enlarges in size and shape. The main value of the ultrasound evaluation at this point is detecting fetal sex, diagnosing abnormalities, and monitoring high-risk pregnancies.

Fetal Sexing³¹⁻³³

The detection of fetal sex in the horse can be successfully done by day 55 of the pregnancy, when the genital tubercle can be clearly visualized by using ultrasonography.^{7,34} The genital tubercle is the embryonic precursor of the penis in males (Fig. 13) and clitoris in females. It migrates during embryonic development to its final destination depending on the fetal sex and appears on the ultrasonographic image as a hyperechoic, bilobed structure. Experienced ultrasonographers can reliably find the genital tubercle in equine fetuses between days 59 and 68. Beyond that time, it is difficult to visualize the vesicle with the fetus in its entirety due to the limited penetration of ultrasound waves when using a transrectal approach. The genital tubercle in female fetuses is found under the tail heads, and in male fetuses, just caudally to the umbilicus. Fetal sexing is more difficult after day 70; however, it can still be done after day 90 by using the transrectal approach, based on the detection of the scrotum in males and the mammary gland in females.³⁴ The

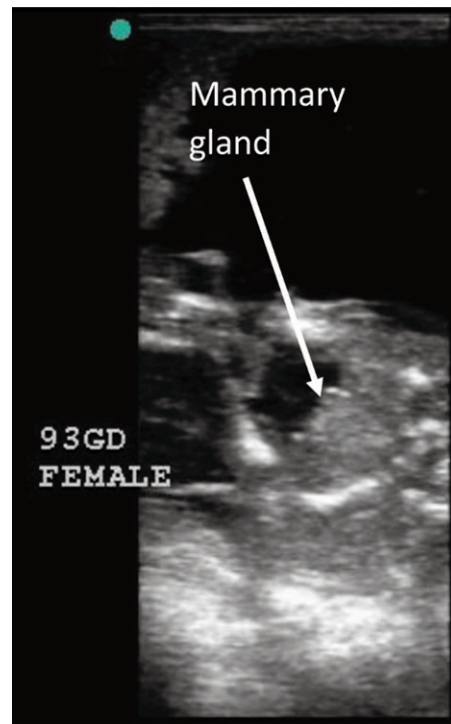


Fig. 14. Ultrasonographic image of the mammary gland in female fetus at 93rd day of gestation.

penis and prepuce can also be identified in male fetuses, using transabdominal ultrasound evaluation between the 100th and 240th days of the pregnancy, whereas mammary glands with teats can be identified in female fetuses between days 90 and 230³⁵ (Fig. 14). Furthermore, large fetal gonads can be visualized after the 90th day of the pregnancy. Female gonads have a central circular echogenic structure surrounded by a hypoechogenic external hollow, whereas male gonads have a homogeneous echotexture and a thin echogenic central longitudinal line (Fig. 15). Color Doppler ultrasonography allows us to visualize the characteristic vascularization of the fetal gonads: cortical vessels in the periphery of the fetal ovary and the central vein that runs through the fetal testis.^{35,36}

Early Embryonic Death

Given that approximately 5% to 15% of equine pregnancies are lost between the 10th and 50th days of gestation,³⁷ the early identification of embryonic demise is important to enter the mare back into the breeding program before the breeding season ends. It is difficult to visualize the signs of early embryonic death (EED) between the 10th and 20th days of gestation given that the embryo proper is not yet visible on the ultrasonographic image. However, any significant changes in the spherical shape of an early embryonic vesicle (under the 16th day of pregnancy), abnormal echogenicity of fluid, or smaller size of the embryonic vesicle than expected, may be

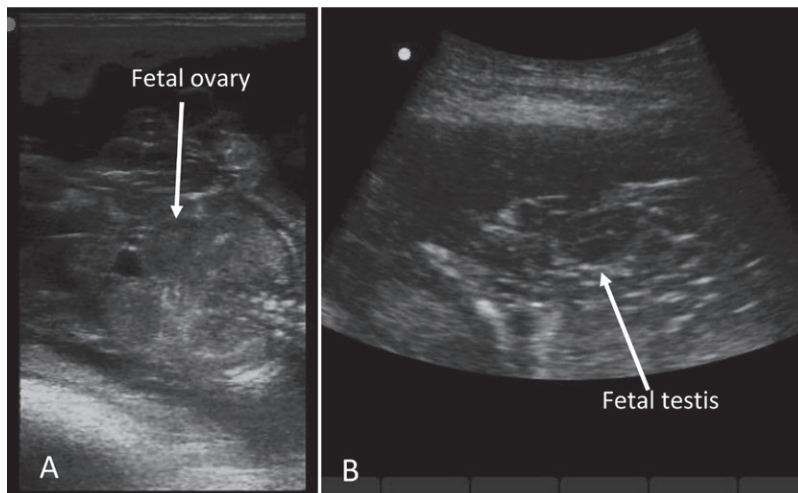


Fig. 15. Ultrasonographic images of fetal gonads: (A) fetal ovaries; (B) fetal testes.

warning signs of an impending embryonic death (Fig. 16).^{37,38} It has been suggested that equine embryos that are small for their day of gestation may not be able to block luteolysis and maintain CL function.³⁷ Degenerating embryos may be found in the body of the uterus beyond day 16 due to the failure of fixation. However, given that the normal embryonic vesicle in the horse looks misshapen at day 17, a particular caution must be taken when interpreting ultrasonographic images of equine pregnancies at this stage. The lack of a heartbeat in the embryo proper seems to be the best indicator of embryonic death. A decrease in the embryonic heart rate can often be seen just before death. In addition, the disorganization of embryonic membranes, slow or lack of growth of the vesicle, low volume of embryonic fluid, and increased echogenic-

ity of embryonic fluids can be observed. Mares may start coming to heat early and build up uterine edema and fluid.

There are various causes of early embryonic loss in the mare. Reduced progesterone concentrations in the mare are not compatible with the maintenance of pregnancy and these lead to embryonic loss. This may be due to the failure to recognize the pregnancy, primary luteal insufficiency, or endometrial irritation causing luteolysis via prostaglandin release. Endometritis provides a hostile uterine environment and induces luteolysis. Even a brief episode of endotoxemia may stimulate prostaglandin release, which causes the lysis of the CL. Aged mares have a significantly higher occurrence of EED than young mares. Various factors contribute to this such as aged gametes leading to chromosomal

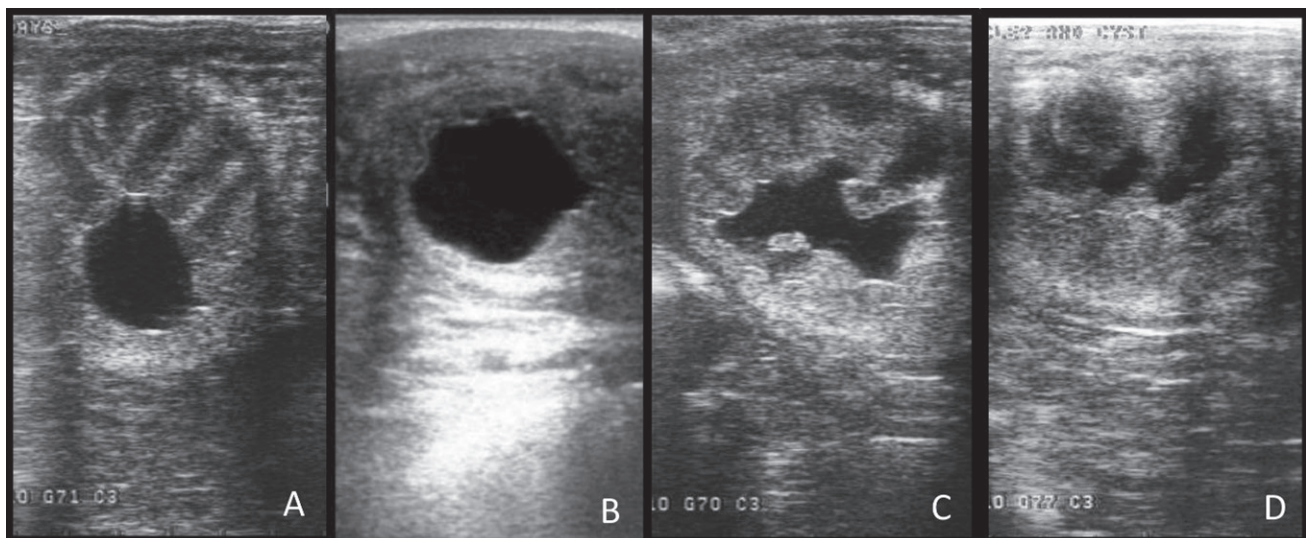


Fig. 16. Ultrasonographic signs of early embryonic death: (A) increased uterine edema; (B) no embryo proper in the embryonic vesicle; (C) no heart beat present; (D) collapsing embryonic vesicle.

defects, degenerative changes in the uterus (periglandular fibrosis), and the high incidence of persistent endometritis or luteal insufficiency. Some incidental embryonic causes of EED, independent of maternal factors, are also identified. The morphological defects of chromosomal aberration may occur spontaneously without maternal involvement.

Twins

Ultrasound imaging is crucial for detecting and managing twin pregnancies in the mare.³⁹ It has been reported that the incidence of double ovulations in Thoroughbred and draft mares is as high as 15% to 25%, but in Quarter Horses, Appaloosa, and ponies, double ovulations occur in 8% to 11%.⁴⁰ Diagnosis is relatively easy between the 13th and 15th days of gestation; however, only if the examiner pays attention to the details, screens the entire reproductive tract several times, and documents the uterine cysts well. Embryonic vesicles migrate through the uterine lumen until the 16th to 17th days of the pregnancy, after which they are fixed at the base of the uterine horn. Twin vesicles are most often fixed in the same horn (unilateral, 70%) but one of them is usually naturally reduced by day 40 (85% of cases), while the remaining embryo survives.⁴¹⁻⁴³ The majority of twins that do not undergo natural reduction by day 40 survive as twins until late pregnancy. Late-term twins are usually aborted, often causing severe dystocia. All bilateral twins (localized in separate horns) survive until late pregnancy and have a similar outcome to that described for surviving unilateral twins (fetal death and abortion). Both fetuses survive to term only rarely and live foals are usually smaller, weaker, and do not perform in their adult life as other horses in their age classifications. This effect is associated with the mare's placentation and the necessity to use the entire uterine surface to properly nourish one fetus. In the case of twins, two fetuses would share the mare's uterus, which leads to the insufficient exchange of nutrients and waste between fetal and maternal circulations.

The early detection and management of twins is a routine task for the equine reproductive specialist. Although research has shown the high incidence of the natural reduction of unilateral twins, it is highly recommended to perform the early reduction of all twins regardless of their location. The best time for manual embryo reduction is during the mobile phase (up to days 16 to 17). The operator can manipulate the uterus and manually separate the embryos, even if they are unilateral, move the targeted embryo to the most desirable location (very tip of the uterine horn), and crush it by using the palm of the hand, fingers (a thumb and an index finger), or the ultrasound probe. This procedure yields a very high success rate if performed before day 20 (90% to 95% survival rate of one embryo).⁴⁴⁻⁴⁶ The reduction of unilateral twins beyond day 17 may be difficult and frustrating, given that embryos are no

longer mobile and the success rate of this procedure significantly decreases. Bilateral twins can still be crushed at day 20, but it should not be attempted after day 25. Since the aggressive manipulation of the uterus during manual embryo crush may cause prostaglandin release, the administration of anti-prostaglandin medication (flunixin meglumine) followed by progestagens (Altrenogest) is highly recommended.

If a twin pregnancy is not detected and reduced on time (by days 20 to 25), other methods are available. Dietary restrictions have not proven to be effective. Blind aspiration of fetal fluids via transvaginal aspiration or surgical removal of the twin is traumatic and should not be used. The transvaginal ultrasound-guided aspiration of the allantoic fluid has a success rate that is lower than manual crush; however, it may be attempted in valuable horses, especially if this is the last chance for this mare to have a foal this season. This method has a variable success rate depending on the gestation age, localization of the vesicles, and experience of the operators. The best results are obtained if performed between days 25 and 35 of gestation, particularly in the case of unilateral twins.⁴⁶ In general, the procedure yields a successful outcome in approximately 50% of cases (20% to 70%), with unilateral twin pregnancy having a significantly lower success rate than bilateral twins.⁴⁵ Specialized equipment is needed for this procedure with a long extension of the ultrasound probe and a long needle. The embryonic vesicle is punctured under the direct guidance of the ultrasonographic image, with the puncture guide displayed on the screen, while the uterus is held close to the vaginal wall by the hand of the operator introduced into the mare's rectum. The ultrasound transducer is inserted into the mare's vagina in an aseptic way and is held next to the wall of the cranial vagina. A needle is inserted by using a single strong thrust through the vaginal wall, peritoneum, and uterine wall, directly into the allantoic cavity or the yolk sac, and the fluid is completely drained. Additional damage to the embryo/fetus can also occur by direct punctures.

An ultrasound probe and the ultrasonographer's hand can be utilized in an attempt to irreversibly damage equine twin fetus between days 60 and 100 of gestation. A smaller fetus is identified and repeatedly traumatized by oscillation or percussion with the ultrasound probe, which may be combined with a membrane slip. Multiple attempts often have to be performed to obtain a desired effect. Approximately 50% of targeted fetuses become unviable after this procedure.⁴⁷

Cranio-cervical dislocation can be performed on the fetus between days 60 and 110 of gestation.^{48,49} It is important to perform this procedure before the placentation process is completed so that the remaining fetus can still "claim" the entire uterine surface for its placental exchange. Initially, this procedure was performed by using both the transrectal and the transabdominal (surgical) ap-

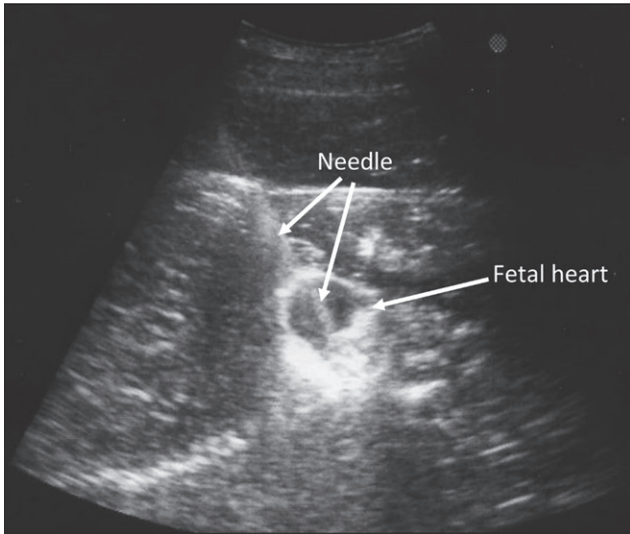


Fig. 17. Ultrasonographic image of ultrasound guided injection of penicillin procaine into the fetal heart.

proaches. Currently, veterinarians that perform this procedure choose the surgical method, given that it yields significantly better results (70% to 80% success rate). A flank incision is made, the uterus is identified by using one arm introduced into the abdominal cavity, and craniocervical dislocation is performed manually on one fetus without incising the uterine wall. The affected fetus may live for a few weeks, but it eventually dies and is expelled as a small mummy at the time of delivery of the remaining fetus at term.

Transcutaneous, ultrasound-guided twin reduction can be performed in mares between days 66 and 168 of gestation. However, this procedure is usually performed between days 115 and 130 of gestation⁵⁰ with a 50% to 60% success rate.^{45,50-52} Fetuses are

identified by using transabdominal ultrasonography. A puncture line is visualized on the screen; this is lined up with the fetal heart and the spinal needle is introduced into the fetal heart with just one or a few fast thrusts. Needle insertion can also be successfully performed without a biopsy line on the screen (Fig. 17). Potassium chloride or penicillin procaine is injected into the heart,^{50,51} causing fetal death during the procedure or soon after. This procedure has to be performed by an experienced, skilled operator and in a very clean, aseptic manner. Treatment with anti-inflammatory/anti-prostaglandin medications and progestagens is initiated, as for all the other above-described procedures.

Late Pregnant Mare

Ultrasonography is used routinely for monitoring high-risk late pregnancies in mares. During this period of time, a veterinarian focuses attention primarily on placental abnormalities and fetal viability. The transrectal and transabdominal approaches have to be used to perform a complete ultrasound examination of the late pregnant mare. Transrectal ultrasound examination can visualize most of the caudal part of the uterus and fetal membranes, called the utero-placental unit. The utero-placental unit is screened for abnormalities such as the thickening or separation of the chorio-allantois from the uterine wall. The combined thickness of the uterus and placenta (CTUP) is measured by using ultrasound calipers and compared with established normal reference values (271 to 300 days of gestation < 8 mm; 301 to 330 days of gestation < 10 mm; beyond 330th day of gestation < 12 mm).⁵³ This measure is always taken from the ventral side of the placental sac, just between the wall of the urinary bladder and a uterine vessel (uterine branch of the vaginal vein), running parallel to the urinary bladder wall (Fig. 18). The increased thickness of

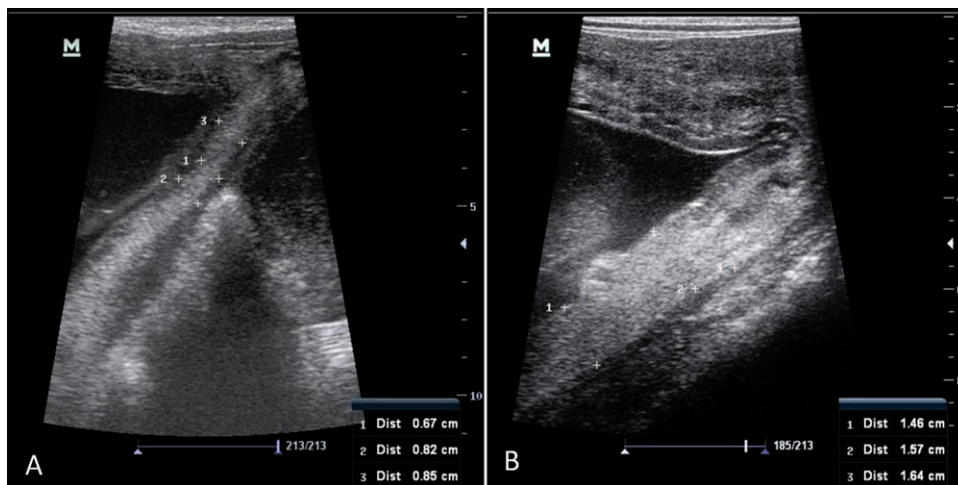


Fig. 18. Transrectal ultrasonographic evaluation of late-pregnant mare and taking measures of the CTUP: (A) normal pregnancy; (B) abnormal pregnancy—increased CTUP and mild placental separation.

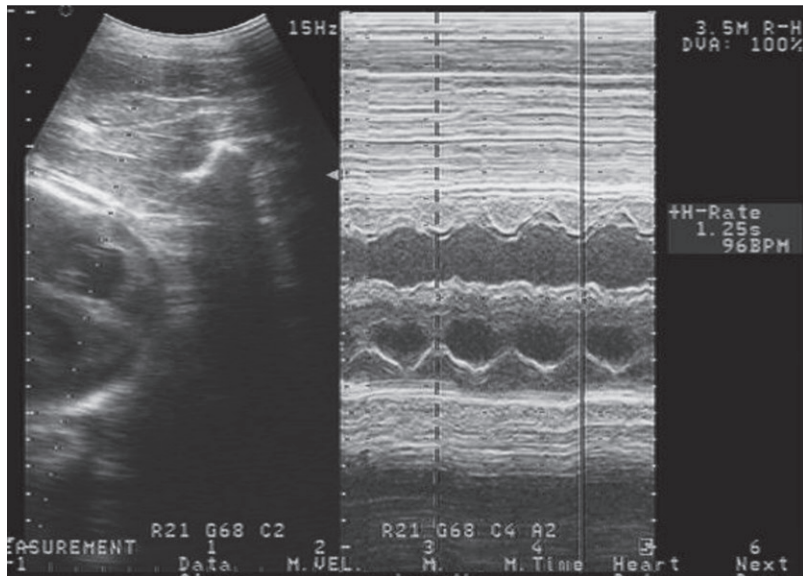


Fig. 19. Transabdominal ultrasonographic evaluation of late-pregnant mare and taking measures of fetal heart rate.

CTUP and/or separation of the chorio-allantois from the endometrium are usually associated with ascending placentitis, which needs to be immediately addressed by aggressive treatment to save the pregnancy.⁵³⁻⁵⁵ Allantoic fluid is usually clear during the ultrasound evaluation of a normal pregnancy; however, it may have an increased number of “free-floating particles” later on in pregnancy, especially after fetal movement or the mare’s transportation. These particles appear hyperechoic. Amniotic fluid can be slightly more cellular than allantoic and create a slight echo on the ultrasonographic image; however, a significant increase in cloudiness (increased echogenicity) and/or thickening of the amniotic membranes are usually associated with the pathological process, often of an infectious nature. Only part of the fetus can be visualized by using the transrectal ultrasonographic approach in the late pregnant mare. The equine fetus usually has an anterior presentation, and therefore the fetal skull is often visualized. Given that the size of the fetal orbit correlates with fetal age, the measurement of the fetal orbit may be obtained to estimate the fetal age in the mare.^{56,57} Fetal movements can also be detected during rectal palpation.

A more detailed examination of the equine fetus can be performed by using transabdominal ultrasound examination. The measurements of CTUP can be taken, assessments of the echogenicity of the fetal fluids done, and fetal organs visualized. The ribcage creates multiple artifacts in the form of black lines, which are the effect of a complete blockage of the ultrasound waves by the ribs.⁷ These shadowing effects obscure the visualization of the fetal internal organs. However, the heart can be clearly visualized in the chest cavity and its movement can be seen. The heart rate is objec-

tively measured by using M-mode (Fig. 19). The fetal heart rate in the horse steadily decreases during pregnancy, starting from 150 to 190 beats per minute (bpm) and decreasing to 60 to 80 bpm (average 75 ± 7 bpm;⁵⁸) in late pregnancy. However, it varies considerably depending on the fetal and mare’s activity and should temporarily accelerate after fetal movement. A consistently slow or very high fetal heart rate is a sign of fetal distress.⁵⁸⁻⁶⁰ If diagnosis is not made early enough and/or treatment is ineffective, the fetus dies and does not have any spontaneous movement and there is no heart beat (diagnostic if the heart is clearly visualized, but no movement and/or Doppler signal seen).

Summarizing, ultrasonography is routinely used for the examination of the reproductive tract in mares. This technique allows the close monitoring of physiological changes during the estrous cycle and diagnosing various pathologies. Furthermore, ultrasonography is necessary to diagnose early pregnancy in the mare and is used for the diagnosis of twins. This technique also allows the close monitoring of late pregnancies and is useful when performing ultrasound-guided reproductive procedures.

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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.

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Ultrasound of Adult Horses

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1. Introduction

Abdominal ultrasound in adult horses is limited by body size. In addition, attenuation of the ultrasound beam and resultant poor image quality is common when the body wall is thick and/or the skin is poorly prepared. Fat in the abdominal wall not only displaces the tissue of interest further from the transducer but fat significantly attenuates the ultrasound beam. In most circumstances clipping should not be required in order to achieve a diagnostic scan but aids in performing scans on obese animals. Isopropyl alcohol is typically applied to skin to improve contact. Ultrasound coupling gel can also be used to further improve contact if necessary. Ideally the scanning depth should be a minimum of 24 cm in adult horses, although 30 cm or greater is preferred. The ideal probe is a low-frequency curved array (curvilinear) probe although a small-footprint phased array probe is also effective. Valuable information can be achieved using 5 to 7.5 MHz linear rectal transducer, although for a complete examination, a lower-frequency probe is required.

Normally a small volume of anechoic peritoneal fluid can be located in most normal horses, typically ventrally or around the duodenum. Failure to identify peritoneal fluid can be normal as the fluid is often transiently located. Furthermore, failure to image fluid should not preclude abdominocentesis if

deemed important to the diagnostic evaluation.^{1,2} Peritoneal fluid should be assessed for volume, echogenicity, fibrin, and gas. Blood has a characteristic echogenic swirling pattern on ultrasound. The presence of hyperechoic fluid with fibrin attached to the peritoneum is common after rupture of an abdominal viscus (Fig. 1).

The liver is most easily imaged on the right side of the abdomen. It can usually be located between the 5th and 16th intercostal spaces (ICSs) from the right cranioventral abdomen through the mid to upper abdomen caudally. Adjacent structures include the right colon and the duodenum (Fig. 2). The liver should not be found ventral to the costochondral junction and if found in that location may infer hepatic enlargement. There is evidence of right hepatic lobe atrophy associated with aging in normal horses,³ such that the number of ICSs where liver is identified on the right side is reduced in horses older than 24 years.⁴ In a study of normal horses, the liver was observed on the right side in 97% of horses and on the left in 71% of animals.⁴ Consequently, failure to identify liver on the left side does not infer disease. On the left side the liver can be imaged from the 4th to the 11th ICSs. The liver should be homogenous and diffusely hypoechoic relative to the spleen, and hyperechoic relative to the renal cortex. The portal vein and caudal vena cava may be seen on the right side and have hyperechoic walls,

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Fig. 1. Septic peritonitis after gastric rupture.

whereas hepatic veins do not. Biliary ducts can also be identified throughout the liver in normal horses.

The spleen is easily located between the 7th ICS and paralumbar fossa on the left side. The organ interfaces dorsocaudally with the left kidney and cranially with the stomach and liver. It is not uncommon for the spleen to cross the ventral midline and extend over to the right side of the abdomen in some normal horses and this does not imply splenomegaly. The caudal border of the spleen should be sharp. Splenic disease can include megaly, neoplasia, abscess, or haematoma (Fig. 3). The spleen is hyperechoic relative to the liver; the organs can be seen in apposition in the left cranial section of the abdomen (Fig. 4).

The left kidney lies deep to the spleen and can be difficult to image in some normal horses, particularly obese animals. Direct apposition of the spleen and kidney is important in ruling out a nephrosplenic entrapment (Fig. 5). In Thoroughbred-type horses the left kidney is approximately 16 × 11 cm and is typically located from the paralumbar fossa

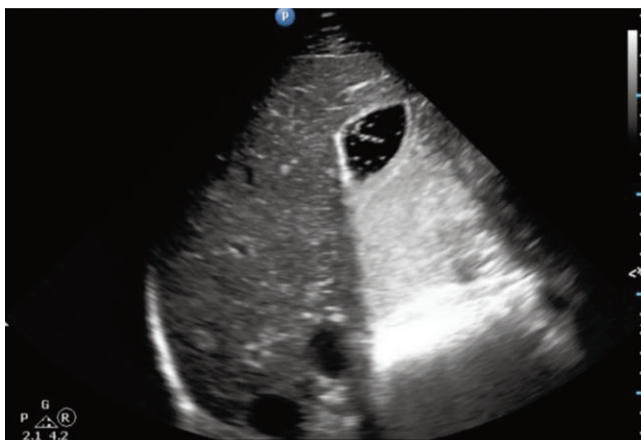


Fig. 2. A right-sided image with liver and duodenum.

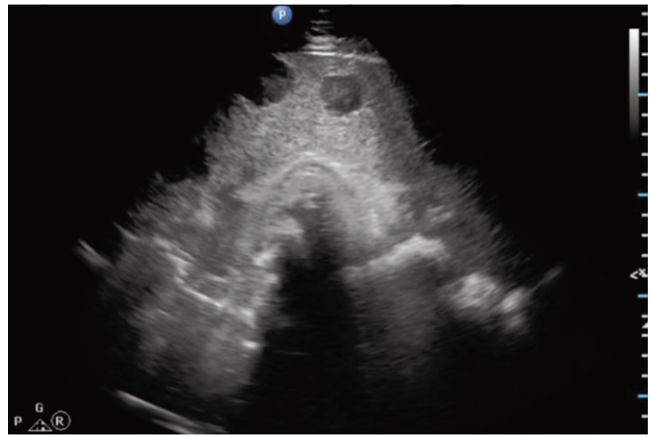


Fig. 3. Left-sided image of a spleen with discrete multifocal lesions due to melanoma.

through to the 15th ICS, 2 cm dorsal to 15 cm ventral to the dorsal aspect of the tuber coxae.⁵ The right kidney is slightly smaller measuring 15 × 10 cm. It is located beneath the transverse processes from the 16th to the 14th ICS, again from 2 cm dorsal to the dorsal margin of the tuber coxae to a point approximately 12 cm ventral.⁵

The stomach is adjacent to the spleen on the left side of the abdomen. In normal horses it is typically found over 2 to 4 ICSs, although this may increase to 5 in normal ponies.¹ The probe should be centered on the 10th ICS in the middle third of the abdomen (in a dorsal to ventral plane) and moved 2 to 3 spaces cranially and caudally. Detection over more than 5 ICSs is consistent with gastric distention in adult horses. Enlargement of the stomach is most commonly due to fluid, but can also be associated with ingesta, gas, or neoplasia (Fig. 6). Distention with fluid is easily seen as a large fluid gas interface. The gastric wall should be less than 7 mm thick.

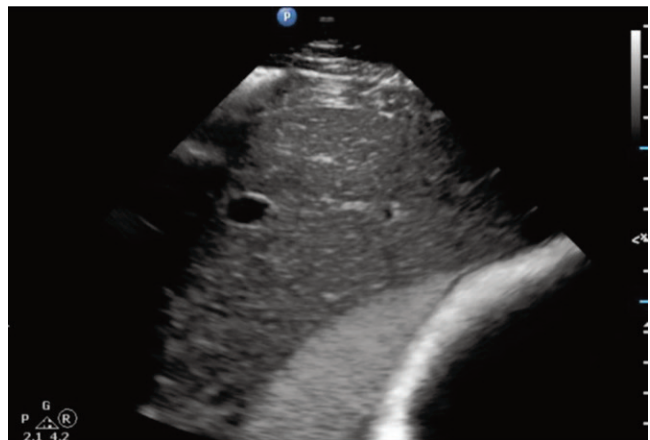


Fig. 4. An image collected in the left cranial abdomen illustrating the relative echodensities of a normal liver and spleen.

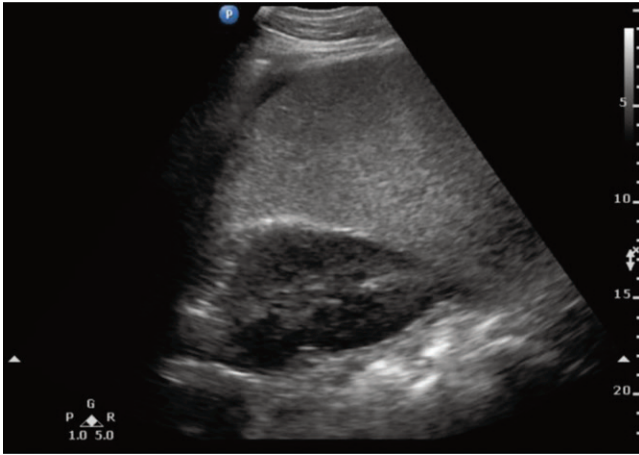


Fig. 5. A left-sided image with the spleen in direct apposition to the kidney.

The duodenum can be consistently located on the right side ventral to the right kidney in the 16th to 17th ICS, and on an imaginary line between the olecranon and the tuber sacrale.⁶ The duodenum is located more cranially in the 14th to 15th ICS in the dorsal part of the middle third of the abdomen,⁷ but identification can be affected by lung interference. The duodenum can also be located in the 12th to 13th ICS traversing between the right hepatic lobe and the right dorsal colon. The duodenal wall is 3 mm (3.0 ± 0.4 mm) thick in normal adult horses.⁸ Wall thickness may be thinner in ponies, particularly younger animals.¹ Intestinal wall thickness is influenced by the degree of distention (thinning) and relative stage of contraction (thickening) so care is required in performing and interpreting measurements.

The jejunum is commonly located in the left caudal abdomen, ventral and medial to the spleen, often around the costochondral junction. It is easily

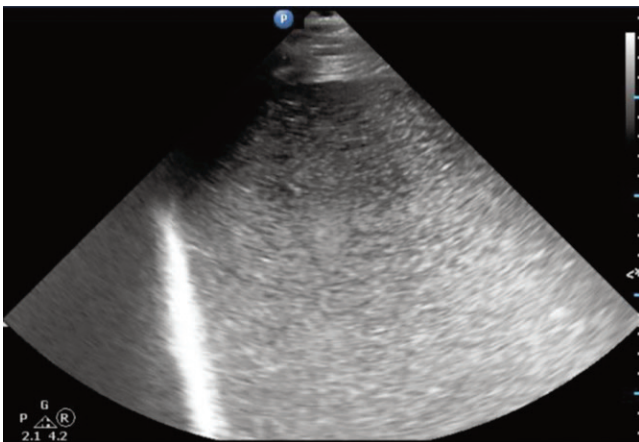


Fig. 6. Gastric dilatation with fluid. Note the fluid gas interface.

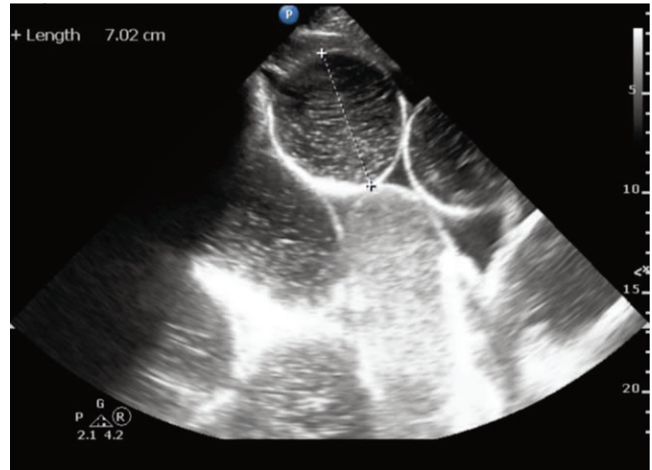


Fig. 7. Small intestinal distension due to a strangulating lesion.

identified by its size, shape, and characteristic movement. Variation in position within the abdomen is common and it can be found in multiple regions, although it is uncommon to identify small intestine in the right caudodorsal abdomen.⁹ Accumulation of distended motile small intestine in the cranioventral abdomen can be consistent with gastrosplenic or epiploic foramen strangulating events (Fig. 7).

The large intestine is recognized by the acoustic shadowing of contents and its large diameter. The presence or absence of sacculations should be noted. The wall thickness of the cecum (4.2 ± 0.3 mm) and ventral colon (3.7 ± 0.1 mm) is greater than the small intestine.⁸ Cecal wall measurements are subject to variability between and within studies. The left and right ventral colon are consistently located in their respective caudoventral and ventral regions. They also feature prominent haustrations. Although the dorsal colon is typically considered to be lacking these structures there are some sacculations at the diaphragmatic flexure and in the right dorsal colon, but these are wider and less prominent than in the ventral colon.⁹

There are a number of conditions that affect the ultrasonographic appearance of the large colon. These include fluid accumulation, tympany, wall thickening due to inflammation or strangulation, and displacement (Fig. 8). Animals with strangulating obstruction of the large colon will have a thickened wall. Horses with colitis are often easy to scan because fluid accumulation within the colon facilitates penetration of the ultrasound beam beyond the mucosa into the lumen. The fluid also acts as a nice contrast agent to better assess the colonic wall. The lower right abdomen should be examined over several ICSs (10th to 14th ICS) at the costochondral junctions for evidence of a right dorsal displacement of the large colon (RDDLC). This is reflected by identifying the colonic vasculature against the body wall, instead of in its normal me-

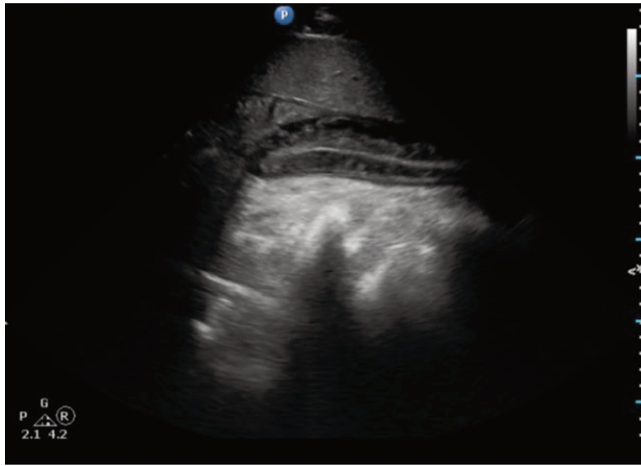


Fig. 8. Increased thickness of the large colon wall due to organ torsion.

dial position. Although abdominal radiography is the preferred method for detecting sand and the accumulation of geosediment in the colon can also be achieved with ultrasound, by identification of hyperechoic colon against the body wall with extensive reflection of the ultrasound beam causing variable shadowing.¹⁰

The concept of performing a rapid ultrasound examination of the abdomen in colicky animals resulted in development of the Fast Localized Abdominal Sonography of Horses (FLASH) examination protocol.⁷ The concept is loosely based on the Focused Assessment with Sonography for Trauma protocol in humans, where 5 views are rapidly obtained from humans in the emergency room (ER) and assessed for fluid in spaces and movement of the lung edges in the pleural cavity. The original FLASH protocol evaluated 7 sites, 4 from the left: ventral abdomen, stomach, reno-splenic window, and the left middle third of the abdomen; and 3 from the right: duodenal window, right middle third of the abdomen, and the cranioventral thorax. The authors reported a scan time approximately 10 minutes and good positive (89%) and negative (81%) predictive values for detecting disease. A recent re-examination of the protocol indicated that it was likely to identify small intestinal lesions and most large intestinal problems, although the horses with RDDLC might be missed as the vessels are often located lower in the right abdomen around the costochondral junctions.¹¹

Thoracic Ultrasound

The thorax should be scanned in a methodical manner given that pulmonary lesions can often be focal. Most equine vets scan in a cranial direction beginning at the 17th ICS and moving through to the 3rd ICS. The probe is orientated within each ICS parallel to the ribs and moved in a dorsal to ventral direction until the diaphragm is reached. The dia-

phragm inserts on the thoracic wall, and from the 8th costal cartilage it curves across the costochondral junctions of the 9th to the 15th ribs to a point midway on the last rib before moving craniomedially to end at the 17th ICS.¹² The probe can be oscillated forward and backward to assess lung and pleural tissue underlying the ribs. The most cranial aspect of lung and the mediastinum can be imaged through the triceps brachii and deltoideus muscles of the shoulder. Alternatively a window under the triceps brachii muscle can give access to this region assuming the leg can be brought forward and the probe orientated toward the cranial mediastinum. For most of the examination a linear or curvilinear probe can be used at a high frequency and reduced depth. A rectal transducer can adequately scan the majority of the lung fields.

The visceral pleura of the normal lung slides evenly over the parietal pleural surface in synchrony with respiration. It has a consistent bright interface indicative of a reflective surface. Associated with this normal interface are horizontal, regularly spaced hyperechoic lines deep to the pleural line that represent reverberation artifact. These are called A lines and are motionless. There is often minimal to no pleural fluid imaged, although a small volume (<3 cm) of anechoic fluid can be found ventrally in normal horses. It is common to observe fat in the ventral thorax in normal horses, which will cause the lung to be displaced medially.

“Comet tails” or “ring-down” artifacts are hyperechoic reflections that originate from the visceral pleural and travel perpendicular to the pleural line into the lung. In the perfectly normal lung there are no “comet tails” because there are no acoustic mismatches as the ultrasound beam passes through the sub-pleural space. In circumstances where abnormal regions in the lung are in contact with the pleural lining there are acoustic mismatches, which cause the artifacts to form (Fig. 9). The reflections are transmitted back to the probe where they are falsely interpreted as hyperechoic structures deeper in the tissue. There are numerous causes of “comet tails” including diseases of the pleural surface and a variety of lung parenchymal conditions. Artifact shadowing can also occur if the beam is not perpendicular to the pleural line, as commonly occurs in the very dorsal aspects of the lung fields.

It is not uncommon to find a few narrow-based “comet tails” in clinically healthy horses, especially ventrally in aged animals. Broad-based “comet tails” or numerous narrow-based artifacts are probably more significant, but ultimately importance should be based on history and clinical findings.

Lung consolidation can lead to pulmonary hepatization, where the ultrasound beam can penetrate the lung because the tissue is devoid of air, giving it an appearance similar to liver (Fig. 10). This can occur with pneumonia or compression atelectasis (see below). Pulmonary abscesses can be seen if in direct contact with the pleural surface. They typi-

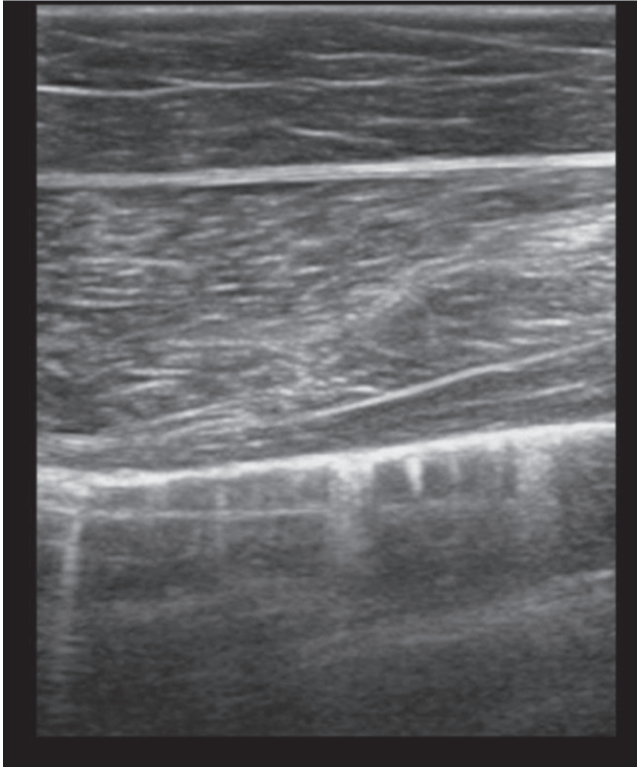


Fig. 9. Lung narrow and broad-based “comet tails.”

cally have a cavitated appearance and are devoid of normal architecture. Echodensity varies depending on contents. *Rhodococcus equi* abscesses commonly occur at the periphery and are therefore easily detected with ultrasound (Fig. 11). Scanning of at-risk foals is an excellent method of detecting disease before clinical presentation, although the diagnosis cannot be definitively confirmed with ultrasound.¹³ The number and size of abscesses may be important in determining whether treatment is required.

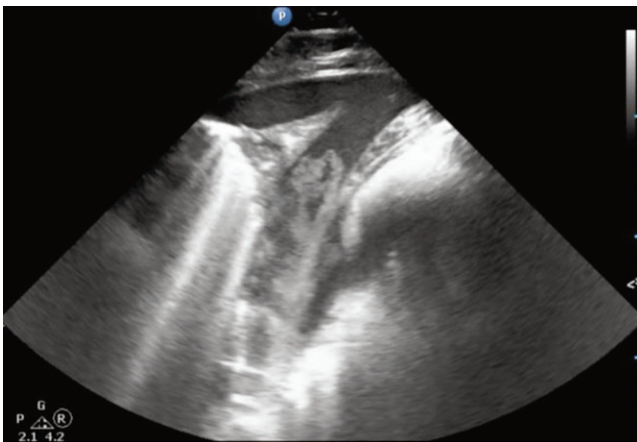


Fig. 10. Pleuropneumonia case illustrating collapsed triangular lung tip, free pleural fluid, and fibrin.

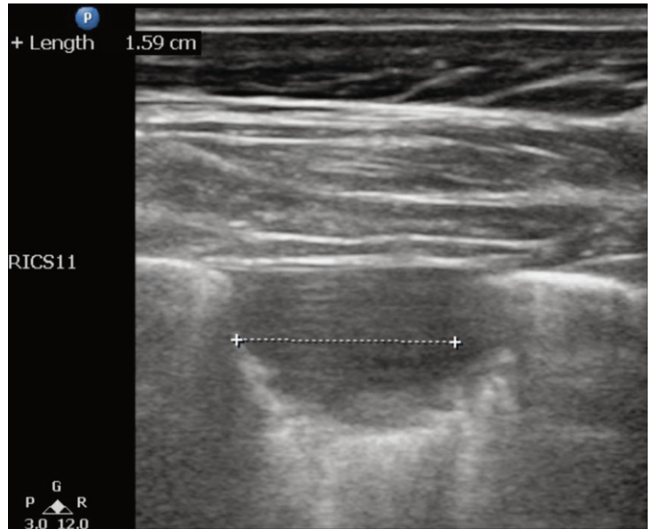


Fig. 11. A nodular lesion in the lung of a foal infected with *Rhodococcus equi*.

Accumulation of pleural fluid is the most common pleural abnormality. Fluid can vary from anechoic through to hyperechoic. Blood in the pleural cavity will appear as a highly cellular, variably echogenic material with a characteristic swirling pattern. Neoplasia (hemangiosarcoma) should be suspected with hemothorax in adult horses, and rib fracture in foals. It is common to scan ribs in foals after dystocia; costochondral dislocation is common, whereas rib shaft fractures are rare but are often symptomatic.

If the volume of fluid is moderate there will be compression atelectasis of healthy lung, lung displacement, and the ventral lung will appear floating in the accumulated fluid (Fig. 10). The effusion will also make 2 normal structures more obvious: the pericardial-diaphragmatic ligament and the tissue that divides the mediastinum cranial to the heart. Infectious pleural effusion is typically echogenic although this may be layered with a greater cell content ventrally. Fibrin can form and attach to the visceral and parietal pleural surfaces. With time the fibrin will become more organized adhering the lung to the thoracic wall and potentially isolating areas leading to focal pleural abscesses. Free gas bubbles in the fluid are often associated with anaerobic bacterial infections.

Pneumothorax is detected by scanning from the most dorsal aspect of the thorax and moving ventrally, carefully looking for a break in the reverberation air artifact. The aerated lung will move with ventilation whereas the air in the pleural space will be static. The lung interface will appear brighter than normal due to atelectasis.

Vascular Ultrasound

The jugular vein is the most common vascular structure that is imaged in clinical practice. This vein

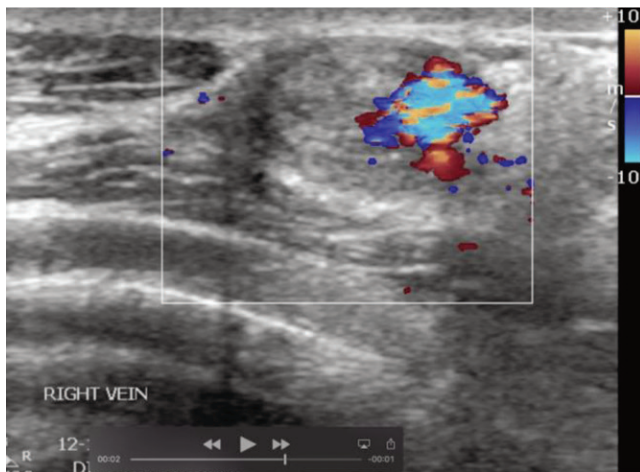


Fig. 12. An image of a jugular vein illustrating partial occlusion with the aid of color flow Doppler.

commonly develops thrombophlebitis associated with catheterization, particularly in horses that are systemically unwell (Fig. 12). The vein can be imaged from the thoracic inlet proximally to the bifurcation into internal and external jugular branches caudal to the vertical ramus of the mandible. The vein is easily collapsed under pressure of the probe so imaging is enhanced with the vein distended. Images should be obtained in transverse and longitudinal planes. A high-frequency (10 to 15 MHz) linear transducer is preferred but a linear rectal transducer can provide diagnostic images. The normal vein has a thin and echogenic wall and the contents will be visible with varying echo density due to restriction of flow. In longitudinal images small venous valves can be seen extending from the wall in normal horses. The carotid artery lies beneath the jugular vein. Flow in both vessels is best assessed with Doppler imaging.

Early changes associated with phlebitis include thickening of the vessel wall, including both the tunica media (middle layer) and the tunica intima (inner layer). Intraluminal thrombi tend to form at the point of vessel damage (catheter entry) and can progress in both directions. Older clots tend to be well organized with smooth margins; active proliferating thrombi on the edges tend to have a more irregular surface. Flow is initially restricted but ongoing proliferation may lead to complete occlusion of the vein. In a transverse view, mature thrombi will have a characteristic laminar pattern. Differentiation of septic from nonseptic thrombophlebitis is important and is supported by clinical and laboratory findings, local heat and pain on palpation and fever, and leukocytosis with a mature neutrophilia, hyperfibrinogenemia, and increased serum amyloid A. On ultrasound, sepsis is supported by a pronounced perivascular swelling, echogenic foci within the thrombus, and fluid accumulation within the clot.

Ocular Ultrasound

Scanning of the eye and orbit is performed in the standing, sedated horse. It is particularly important to perform in horses with ocular trauma or with evidence of intraocular masses. The examination is facilitated by an auriculopalpebral block and application of a topical aesthetic agent to the cornea. The examination is usually performed through the closed eyelid, although better images are achieved with the probe directly on the cornea if it is free of disease.¹⁴ Standard ultrasound contact gel should not be placed directly on the globe. A safer alternative is a sterile gel, such as KY jelly. Ideally a high-frequency (>10 MHz) linear transducer is used. The cornea, anterior and posterior lens capsules, retina/sclera, and ciliary body are all well-defined hyperechoic structures within the globe. The corpora nigra is located at the pupillary margin within the anterior chamber; these are subject to cyst formation with a characteristic anechoic center. Intraocular neoplasia is more commonly homogeneous. The anterior chamber is hypoechoic and therefore the accumulation of fibrin, blood (hyphema) or white blood cells (hypopyon) increases the echodensity of the aqueous humor. Cellular responses (hyphema, hypopyon) tend to settle ventrally within the chamber. The body of the lens is normally anechoic; cataract formation will result in increased opacity and the lens may vary in size. The lens capsule may also appear brighter.

Ultrasound permits some assessment of the posterior segment if there is anterior chamber disease or cataracts preventing ophthalmoscopic examination of the fundus. Retinal detachment is seen as a thin hyperechoic structure prolapsing into the vitreous. The retina often maintains attachment at the optic nerve and ora ciliaris retinae, producing a "seagull" sign.¹⁴ Smaller degrees of detachment will not have this appearance.

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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Ultrasound of Foals—Your Eyes into the Pediatric Patient

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1. Introduction

Although ultrasound technology has improved substantially during the past 2 decades, with an associated reduction in cost, scanning and interpretation of the heart in all aged animals remains a major challenge for even experienced practitioners. The need for echocardiography is typically due to persistent or atypical cardiac murmurs. This examination requires good equipment, experience, and expertise for accurate interpretation. Much of the age-related changes in heart size was published by Stewart and others in 1984¹, who reported M-mode parameters from birth through 3 months of age. They reported a number parameters that were positively correlated with age and body weight, including both left ventricular (LV) and right ventricular end-diastolic diameters (EDDs), the thickness of the interventricular septum, and the thickness of LV free (posterior) wall. For example, the LV EDD and LV end systolic diameter (ESD) increased from 6.04 and 4.58 cm to 7.76 and 6.92 cm, respectively, during the first 3 months of life. For comparison, the LV EDD and LV ESD in a typical adult Thoroughbred is 12 and 7.5 cm, respectively.

Foals by their relatively small size and limited adipose tissue are usually amenable to comprehensive abdominal ultrasound examinations. Examples

of diseases detected on abdominal ultrasound include uroperitoneum, necrotizing enterocolitis with gas shadows seen in the intestinal wall (Fig. 1), septic peritonitis, and intussusceptions. In older foals with hypoproteinemia small-intestinal thickening due to Lawsonia can be easily imaged (Fig. 2).

2. Umbilical Scanning in Neonates

Scanning of the umbilicus is recommended in all sick foals, particularly those with localized or systemic evidence of sepsis. Ideally the hair on the ventral midline of the abdomen is clipped from the xiphoid to the inguinal area, but application of isopropyl alcohol is often adequate without clipping. The scan can be performed with the foal standing or in lateral recumbency. Dorsal recumbency affords the best access but care should be taken as this positioning has an adverse effect on ventilation. The preferred probe is a high-frequency (10 to 14 MHz) linear transducer, although diagnostic scans can be performed with a 5-to-7.5-MHz linear rectal probe.

Structures are imaged in both longitudinal and transverse planes. It is helpful to adhere to a routine so as not to miss any structures. The external umbilical remnant contains the two umbilical arter-

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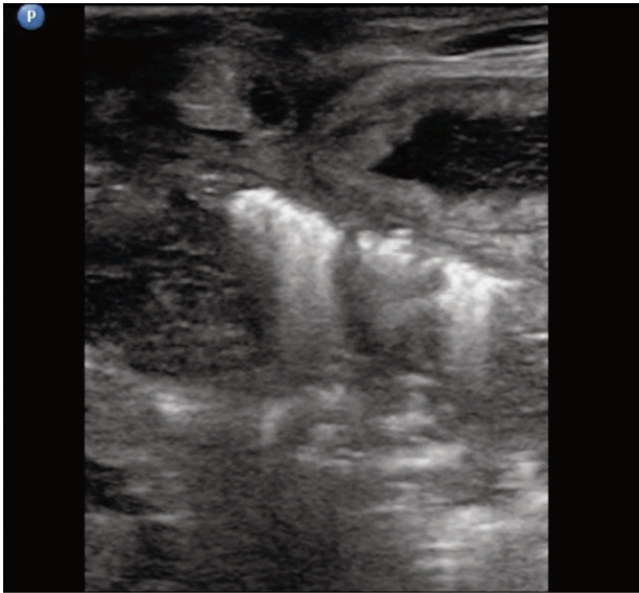


Fig. 1. Necrotizing enterocolitis in a young foal with gas shadows within the colonic wall.

ies, the umbilical vein and the urachus. In the normal foal the structures will rapidly atrophy after the cord has naturally severed; sharp transection of the cord will delay this normal response. Infection of this structure is usually easily identified through palpation and ultrasound. The stump may be thickened with a core with variable echogenicity. Gas may be present and is seen as bright hyper-echoic flecks.

The umbilical vein lies cranial to the umbilicus and is very superficial running in a reflection of the peritoneum (Fig. 3). As you approach the xiphoid cartilage the vein will move deeper and enter the liver. The vein has a flattened, elliptical shape with a thin wall and hypoechoic center. The diam-



Fig. 2. Small-intestinal wall thickening due to infection with *Lawsonia intracellularis*.

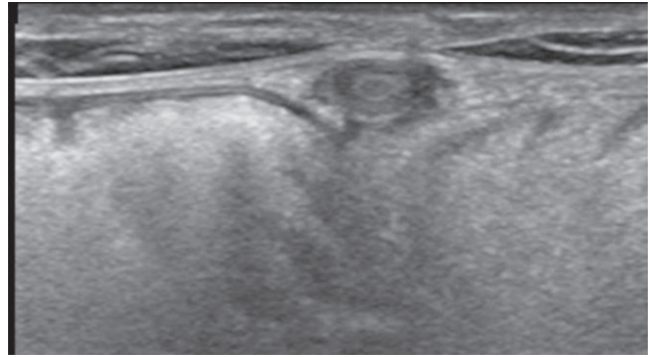


Fig. 3. Normal ellipsoid umbilical vein.

eter should not exceed 10 mm and does narrow as it moves cranially. In contrast the paired umbilical arteries run caudally from the umbilicus. The arteries separate and move deeper into the abdomen where they run on the lateral walls of the bladder, ultimately becoming the round ligaments of the bladder. The arteries in isolation should be less than 10 mm diameter. Asymmetry of arteries is common and is normal.

The urachus, the anatomical connection between the bladder and the allantois, is located between the arteries. A combined measurement of the arteries and urachus just caudal to the umbilicus is made from a transverse view and should be less than 25 mm (Fig. 4). Reopening of the urachus is common after birth in sick foals, possibly associated with muscular weakness. Ultrasound examination is typically normal, i.e., thin walled with a hypoechoic center, although in some cases patency may be associated with infection. Infection will often cause the combined measurement of arteries and urachus to increase.

Disruption of the urinary tract most commonly involves a tear of the urinary bladder, but in some cases the tear may be in the urachus. If the

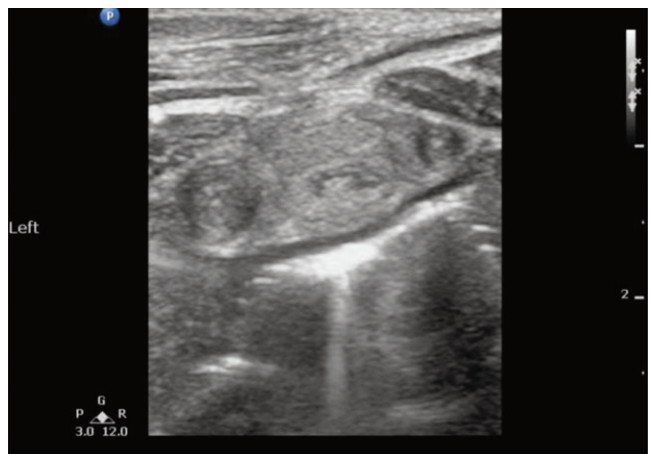


Fig. 4. Paired umbilical arteries and urachus.

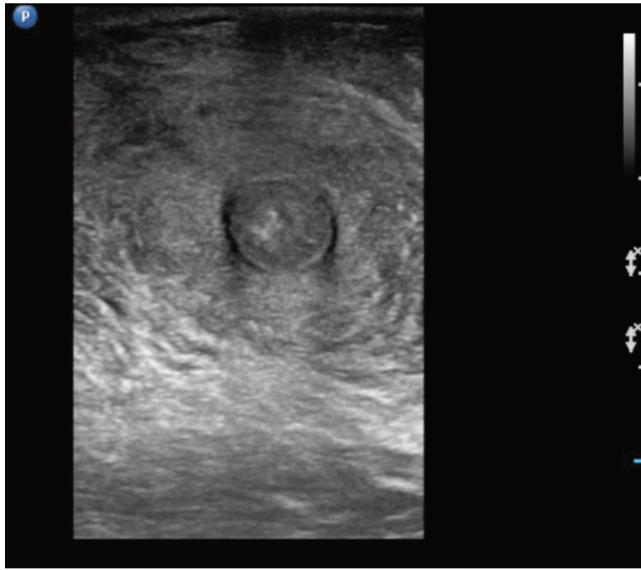


Fig. 5. External umbilical abscess.

urachal tear is close to the bladder it will result in uroperitoneum, but if the leak is closer to the umbilicus it can result in subcutaneous swelling.

It is important to note that infection of the umbilical remnants can be obvious externally (Fig. 5), but often is only apparent on ultrasound examination when internalized (Fig. 6).



Fig. 6. Internal umbilical infection.

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.

Reference

1. Stewart JH, Rose RJ, Barko AM. Echocardiography in foals from birth to 3-months old. *Equine Vet J* 1984;16(4):332-341.

Methicillin-Resistant *Staphylococcus aureus* Colonization and Infection in Thoroughbred Racehorses and Equine Veterinarians in Japan

Taisuke Kuroda, DVM, PhD*; Yuta Kinoshita, DVM, PhD; Hidekazu Niwa, DVM, PhD; Norihisa Tamura, DVM; Kentaro Fukuda, DVM; and Yoshinori Kasashima, DVM, PhD

Methicillin-resistant *Staphylococcus aureus* (MRSA) were isolated from nine infected horses and 16 healthy veterinarians in two racehorse hospitals, and genetic analysis suggested the MRSA transmission between veterinarians and MRSA-infected horses. Authors' address: Equine Research Institute, Japan Racing Association, 1400-4, Shiba, Shimotsuke, Tochigi 329-0412, Japan; e-mail: taisuke.kuroda@equinst.go.jp. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Methicillin-resistant *Staphylococcus aureus* (MRSA) infections have been confirmed in hospitalized Thoroughbred racehorses at the hospitals of two training centers in Japan. To investigate the source of infection, we examined the nasal MRSA colonization in healthy Thoroughbred racehorses, veterinarians, and office staff at the racehorse hospitals of the two training centers.

2. Materials and Methods

We took the nasal swabs from 600 healthy Thoroughbred racehorses, 53 veterinarians, and 16 office staff. SCCmec, multilocus sequence typing (MLST), and pulsed-field gel electrophoresis (PFGE) were performed for genetic characterizations of MRSA strains. Nine MRSA isolates from infected horses hospitalized at these hospitals were used for comparisons of genetic characterizations.

3. Results

MRSA was not isolated from the healthy racehorses and office staff, but was isolated from 16 veterinarians (30.1%). Ten of 16 strains were classified as SCCmec type II-ST5 and 6 of 16 were classified as SCCmec type IV-ST8. All nine strains isolated from the infected horses were classified as SCCmec type II-ST5. PFGE typing indicated that 19 strains of the SCCmec type II-ST5 strains isolated from veterinarians and infected horses were genetically identical or highly similar.

4. Discussion

These results indicated the occupational risk of MRSA colonization in veterinarians. Moreover, PFGE typing suggested that SCCmec type II-ST5 strains were transmitted between veterinarians and infected horses. Hygiene management may be required to prevent MRSA infections in horses and colonization in veterinarians.

Research Abstract—for more information, contact the corresponding author

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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.

Effects of Feeding Frequency Using a Commercial Automated Feeding Device on Gastric Ulceration in Exercised Quarter Horses

Luke Bass, DVM, MS, DABVP (Equine)*; Elsbeth Swain, DVM, DACVIM; Hugo Santos, PhD; Tanja Hess, DVM, PhD; and Jerry B. Black, DVM

This is the first study that suggests a commercial feeder can be utilized in young Quarter Horse-type performance horses to decrease the incidence of gastric ulceration. Authors' address: College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523; e-mail: Luke.bass@colostate.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Feeding horses meals containing high-percentage starch-based concentrates have been associated with problems such as gastric ulcers and colic. Our objective was to evaluate two grain-feeding regimens: traditional grain feeding (twice a day; TF) compared with horses fed with an automated feeder programmed to deliver grain in 20 equal aliquots (FF) throughout the day and its effects on gastric ulceration, body weight, and body condition score (BCS).

2. Materials and Methods

Thirty-one Quarter Horses were maintained in individual stalls during the experimental period and worked at moderate exercise intensity. Sixteen horses were fed via FF having its total daily grain amount aliquoted and released every hour for 20 consecutive hours. Fifteen horses were fed via TF two times a day. Both groups received 60% of dry matter intake (DMI) as forage split into two feed-

ings. Gastrosopies were performed before grain adaptation (0), 30, and 60 days. Weight and BCS were evaluated biweekly with feed intake measured daily.

3. Results

There were no changes in gastric ulcer scores in FF horses and higher gastric ulcer scores in TF horses over time. No significant differences were found when comparing the two groups for BCS, body weight, and feed intake/wastage throughout the time period.

4. Discussion

Time between meals in the study was shown to cause a significant increase in gastric ulcer scores in the TF group and no significant increase in the FF group when comparing the two groups of similarly housed and trained young horses.

Research Abstract—for more information, contact the corresponding author

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Acknowledgments

All protocols were approved by the institutional animal care and use committee at Colorado State University.

Funding for this study was provided by iFEED. They were not involved in study design, data collection and analysis, or in the decision to publish or in manuscript/abstract preparation or approval.

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.

Effect of Phenylbutazone Versus Firocoxib on Fecal Microbiota Composition and Diversity of Horses

Canaan M. Whitfield-Cargile, DVM, PhD*; Lauren M. Richardson, DVM; Ana M. Chamoun, PhD; Hannah J. Dockery, and Noah D. Cohen, VMD, MPH, PhD, DACVIM

Both nonselective and selective nonsteroidal anti-inflammatory drugs cause a temporary alteration of the fecal microbiota of adult horses when given for 10 days. Authors' address: Department of Veterinary Large Animal Clinical Sciences, College of Veterinary Medicine & Biomedical Sciences, Texas A&M University, 4475 TAMU, College Station, TX 77843-4475; e-mail: cwhitfield@cvm.tamu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Nonsteroidal anti-inflammatory drugs (NSAIDs) are frequently administered in equine medicine. NSAID-induced gastrointestinal (GI) injury is a frequent adverse event associated with NSAID use and evidence exists that NSAIDs induce GI microbial imbalance (dysbiosis) in other animals and people. Cyclooxygenase (COX)-2-selective NSAIDs are thought to result in less GI damage. It is unknown, however, whether NSAIDs alter the fecal microbiota of horses. Therefore, our objectives were to determine whether the composition and diversity of the fecal microbiota of adult horses were altered by NSAID use and whether these effects differed between COX-2-selective NSAIDs and nonCOX-selective NSAIDs.

2. Materials and Methods

Twenty-five adult horses were randomly assigned to one of three groups: control (n = 5), phenylbutazone (n = 10), or firocoxib (n = 10). Treatments were administered for 10 days. Fecal samples were collected on days 0, 5, 10, 15, 20, and 25. DNA was

extracted from feces and the 16S rRNA gene amplified and sequenced to determine the composition and diversity of the microbiota.

3. Results and Discussion

Although the fecal microbiota profile of the control group remained stable over time, the phenylbutazone and firocoxib groups had decreased diversity and alteration of their microbiota profiles that were most pronounced at day 10. Dysbiosis has been linked to several important diseases of horses including colic, laminitis, and infections from enteric pathogens and these findings suggest that commonly administered NSAIDs result in dysbiosis of 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.

Research Abstract—for more information, contact the corresponding author

NOTES

Investigating the Response of Exercise-Induced Pulmonary Hemorrhage to Different Potential Prophylactic Treatments

Warwick Bayly, BVSc, MS, PhD*; Carolina Lopez, DVM; Raymond Sides; Gerald Bergsma, DVM; Jenyka Bergsma, DVM; Macarena Sanz, DVM, PhD; Jenifer Gold, DVM; Todd Coffey, PhD; and Debra Sellon, DVM, PhD

Treatment with 0.5 mg/kg furosemide IV 24 hours before strenuous exercise, when combined with controlled access to water, shows potential for attenuating the severity of exercise-induced pulmonary hemorrhage (EIPH) in racehorses. Authors' addresses: Department of Veterinary Clinical Sciences (Bayly, Lopez, Sides, Sanz, Gold, Sellon) and Center for Interdisciplinary Statistical Education and Research (Coffey), Washington State University, Pullman, WA 99164-6610; and Cavalli Equine Veterinary Services, Auburn, WA 98001 (G. Bergsma, J. Bergsma). e-mail: wmb@wsu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

There is growing pressure in the United States to eliminate race-day furosemide administration despite its efficacy in reducing the severity of exercise-induced pulmonary hemorrhage (EIPH). No effective alternative therapies have been identified. We investigated some alternatives that might attenuate EIPH.

2. Methods

Six horses underwent treadmill exercise to fatigue 24 hours after the initiation of seven treatment protocols: 0.5 and 1.0 mg/kg furosemide IV with and without controlled access to water; 24-hour controlled access to water; 4 hours after 0.5 mg/kg furosemide IV, and a placebo. Bronchoalveolar lavage (BAL) erythrocyte count was determined before and 45–60 minutes post-exercise. The latter fol-

lowed an endoscopic examination for assignment of an EIPH score. Body weight, urinary volumes and ion excretions, plasma and intraerythrocytic ion concentrations, and fecal water and water intake were monitored from beginning treatment until just before exercise. Data were analyzed using linear mixed-effects models, and the most promising treatment further evaluated using endoscopy and BAL following simulated races.

3. Results

Furosemide, 0.5 mg/kg, combined with controlled access to water significantly reduced the severity of EIPH. No ill effects were detected in the horses.

4. Discussion

Although the findings were promising, the number of horses used was small. The effects of furosemide

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on water and ion excretion were evident for 24 hours but did not adversely affect the horses, likely because of increased absorption of water and ions from the colon.

Acknowledgments

This work was funded in part by the Grayson-Jockey Club Research Foundation, the AAEP, Churchill Downs, Del Mar Thoroughbred Club, Keeneland Racetrack, Kentucky Downs, The Stronach Group, New York Racing Association, Oak Tree Racing Association, Oaklawn Racetrack, and the Thoroughbred Horseman's Association.

The invaluable assistance of Dr. Tom Wilkinson, Marshall Allen, Jack Hodge, and Emerald Downs

Racing LLC, Christina Frost, Elena Kremer, Sarah Eichler, Linnea Warlick, Jenna Moline, Nick Hall, Gabriela Baers, Jacob Cenicerros, Loren Normandeau, Karen Hoagland, Dominic Eickert, Zena Hemmen, Halle Williams, Jared Hardaway, Janaki Swanson, Josh Packer, and Kade Grende is gratefully acknowledged.

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.

Efficacy of Furosemide Dosed 4- Versus 24-Hours Pre-Race

Heather K. Knych, DVM, PhD, DACVCP*; W. David Wilson, BVMS, MS;
Alina Vale, DVM; Philip H. Kass, DVM, MPVM, PhD; Rick M. Arthur, DVM;
and Jim Jones, PhD, DVM

Whereas none of the treatments prevented exercise-induced pulmonary hemorrhage (EIPH) in these horses, reduced red blood cell (RBC) counts in bronchoalveolar (BAL) fluid post-race indicated that administering furosemide 4 hours before a race was the most effective of the three treatments for reducing the severity of EIPH. Authors' addresses: K.L. Maddy Equine Analytical Chemistry Laboratory, (Knych); Department of Medicine and Epidemiology, (Wilson, Arthur), Department of Surgical and Radiological Sciences (Jones), School of Veterinary Medicine, University of California–Davis, Davis, CA 95616; and 7934 Artesian Road, San Diego, CA 92127 (Vale); e-mail: hkknych@ucdavis.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Due to the high prevalence of exercise-induced pulmonary hemorrhage (EIPH) in racehorses and the potential effect on the horse's health, furosemide administration is permitted up to 4 hours prior to post time in most North American racing jurisdictions. Anecdotal reports suggest that administration of furosemide 24 hours prior to strenuous exercise may be equally effective in decreasing the severity of EIPH.

2. Materials and Methods

Fifteen Thoroughbred racehorses received 5 mL of 0.9% NaCl or 250 mg of furosemide either 4 or 24 hours prior to a 5-furlong simulated race. Blood samples were collected pre- and post-race for determination of furosemide, lactate, hemoglobin, and electrolyte concentrations. One-hour post-race, an endoscopic exam and bronchoalveolar lavage (BAL) was performed by an investigator

blinded to treatment. Horses were assigned an EIPH score based on previously published criteria and the number of red blood cells (RBC) in BAL fluid was determined.

3. Results and Discussion

There was a statistically significant difference in EIPH scores between the 4-hour and 24-hour ($P = .03$) furosemide administrations. RBC counts were significantly different between the saline and 4-hour furosemide groups ($P = .009$) but not between the saline and 24-hour furosemide treatment group ($P = .260$) or between the 4-hour and 24-hour treatment groups ($P = .520$).

Acknowledgments

Funding for this study was provided by the Grayson-Jockey Research Foundation, The American Association of Equine Practitioners Foundation, Churchill Downs, Del Mar Thoroughbred Club, Keeneland As-

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sociation, Kentucky Downs, The Stronach Group, New York Racing Association, Oak Tree Racing Association, Oaklawn Park, and the Thoroughbred Horseman's Association. The authors would like to acknowledge Kelsey Seminoff, Stacy Steinmetz, Alexandria White, Kendra Mitchell, Briana Hamamoto and Drs. Scott Stanley, Jeff Blea, Ryan Carpenter, Scott Hay, Kim Kuhlmann, Don Smith, Roger Hunter, Raina Petrov, and Linda Harrison for their assistance with this project.

Declaration of Ethics

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

Conflict of Interest

Dr. Rick Arthur serves as a member of the board of directors of the Oak Tree Racing Association. No other authors have conflicts.

Effect of Selective Versus Non-Selective Cyclooxygenase Inhibitors on Gastric Ulceration Scores and Intestinal Inflammation in Horses

Lauren M. Richardson, DVM*; Canaan Whitfield-Cargile, DVM, PhD;
Noah D. Cohen, VMD, MPH, PhD, DACVIM; Ana Chamoun, PhD; and
Hannah Dockery

Cyclooxygenase-2-selective nonsteroidal anti-inflammatory drugs (NSAIDs) result in less severe ulceration of the gastric glandular mucosa. Glandular ulceration was significantly correlated with fecal albumin concentration, suggesting that fecal albumin may serve as a noninvasive diagnostic marker for NSAID-induced gastrointestinal injury. Authors' address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Texas A&M University, College Station, TX 77843-4475; e-mail: LRichardson@cvm.tamu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Nonsteroidal anti-inflammatory drugs (NSAIDs) are frequently administered and can cause gastrointestinal (GI) injury, including gastric ulceration and right dorsal colitis. A strategy to limit NSAID-induced intestinal damage is to administer cyclooxygenase (COX-2)-selective NSAIDs. It is unknown, however, whether COX-2-selective NSAIDs result in less GI injury vs nonselective NSAIDs in horses. The objective of this study was to compare the effects of a COX-2-selective (firocoxib) and a nonselective (phenylbutazone) NSAID on gastric ulceration and on a fecal marker of lower GI tract injury (albumin).

2. Materials and Methods

Twenty-five adult horses were randomly assigned to receive placebo (n = 5), phenylbutazone (n = 10), or firocoxib (n = 10). Treatments were administered on days 1 to 10. Gastroscopy was performed on days 0 and 10 and fecal samples were collected on days 0, 10, and 25. Fecal albumin was quantified via ELISA.

3. Results

Both classes of NSAIDs induced gastric ulcers, but ulcer severity was greater within the glandular stomach for phenylbutazone-treated horses. Fecal albumin concentration was significantly associated with glandular ulcer scores irrespective of treatment.

4. Discussion

These findings suggest that COX-2-selective NSAIDs result in less ulceration of the glandular mucosa than non-COX selective NSAIDs. Fecal albumin was associated with glandular ulcer scores and did not differ between treatment groups.

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.

Research Abstract—for more information, contact the corresponding author

NOTES

Effect of Feeding on the Pharmacokinetics of Oral Minocycline in Healthy Adult Horses

Kate O. Echeverria, DVM, MS†; Kara M. Lascola, DVM, MS*;
Steeve Giguère, DVM, PhD, DACVIM; and Jonathan H. Foreman, DVM, MS

Delaying feeding of hay after oral administration of minocycline improves drug bioavailability in adult horses. Authors' addresses: Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois, 1008 West Hazelwood Drive, Urbana, IL 61802 (Echeverria, Lascola, Foreman); and Department of Large Animal Medicine, College of Veterinary Medicine, University of Georgia, 2200 College Station Road, Athens, GA 30605 (Giguère); e-mail: klascola@illinois.edu. *Corresponding author; †presenting author. © 2017 AAEP.

1. Introduction

The administration of minocycline in adult horses has grown in popularity and studies suggest superior oral bioavailability when compared to doxycycline. Unfortunately, there is limited information regarding the impact that feeding may have on oral bioavailability of this drug in adult horses.

2. Materials and Methods

Six healthy adult horses were administered intravenous (2.2 mg/kg) and oral minocycline (4 mg/kg) with access to hay provided at the time of oral drug administration (fed group) and with access to hay delayed for 2 hours after oral drug administration (fasted group) using a Latin Square crossover design and a 7-day washout period between treatments. Plasma concentration versus time data was analyzed based on non-compartmental pharmacokinetics.

3. Results

When comparing fasted to fed horses, mean \pm SD bioavailability (fasted, 38.6% \pm 4.6; fed, 15.7% \pm 2.3), and maximum plasma concentration (C_{max}) (fasted,

1.343 \pm 0.418 μ g/mL; fed, 0.281 \pm 0.157 μ g/mL) were both greater in fasted horses ($P < .05$, both). Median (range) time (h) to maximum plasma concentration (T_{max}) in fasted horses was 2.0 (1.5 to 3.5) and in fed horses was 5.0 (1.0 to 8.0) and was not significantly different between groups.

4. Discussion

In adult horses, delaying access to hay for 2 hours after oral minocycline administration improved drug bioavailability. This has important implications given that optimizing antimicrobial plasma concentrations is critical for effective treatment of bacterial infections in adult horses.

Acknowledgments

Supported by the American Quarter Horse Association.

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.

Research Abstract—for more information, contact the corresponding author

NOTES

Maternal Vaccination Against Poly-*N*-acetyl Glucosamine Protects Foals Against Intrabronchial Infection with *Rhodococcus equi*

Colette Cywes-Bentley, PhD; Joana N. Rocha, MS;
Angela I. Bordin, DVM, MS, PhD; Daniel R. Vlock, MD, PhD;
Gerald B. Pier, PhD; and Noah D. Cohen, VMD, MPH, PhD, DACVIM*

Maternal vaccination against the polysaccharide poly-*N*-acetyl glucosamine (PNAG) protects foals against *R. equi* pneumonia. Authors' addresses: Equine Infectious Disease Laboratory, Department of Large Animal Clinical Sciences, College of Veterinary Medicine & Biomedical Sciences, Texas A&M University, College Station, TX 77843 (Cohen, Rocha, Bordin); ALOPEXX Enterprises, LLC, Concord, MA 01742 (Vlock); and Department of Medicine, Harvard Medical School and Brigham & Women's Hospital, Harvard University, Boston, MA 02115 (Cywes-Bentley, Pier); e-mail: ncohen@cvm.tamu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Rhodococcus equi is an important cause of foal pneumonia for which a vaccine is lacking. *Rhodococcus equi* expresses the highly conserved surface polysaccharide poly-*N*-acetyl glucosamine (PNAG).

2. Materials and Methods

Using a randomized, blinded, controlled study design, the efficacy of maternal vaccination with a vaccine composed of an oligosaccharide fragment of deacetylated PNAG conjugated to tetanus toxoid (AV0328; ALOPEXX, LLC) was evaluated. Pregnant mares (n = 19) received IM injections 6 and 3 weeks prior to foaling with either AV0328 plus adjuvant (n = 12) or saline (n = 7). Foals were infected intrabronchially at approximately 28 days of life with 1×10^6 live, virulent *R.*

equi and monitored for development of culture-confirmed *R. equi* pneumonia. Blood and colostrum samples were collected to detect binding and functional antibodies to PNAG from mares and foals.

3. Results

Only one of 12 foals from vaccinated mares developed *R. equi* pneumonia, whereas six of seven controls became pneumonic ($P = .0017$; Fisher's exact test). Affected foals displayed clinical findings consistent with *R. equi* pneumonia, had positive cultures and cytologic evidence of *R. equi* pneumonia in tracheobronchial fluid, and required antimicrobial treatment to resolve infection. Protected foals born to vaccinated mares had none of these findings and did not require treatment following challenge. Anti-PNAG titers were significantly ($P < .05$) higher

Research Abstract—for more information, contact the corresponding author

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in vaccinated mares and their foals than those of control mares and their foals.

4. Discussion

Maternal vaccination against PNAG can protect foals against *R. equi* pneumonia.

Acknowledgments

Dr. Cywes-Bentley and Ms. Rocha contributed equally as lead authors. Drs. Pier and Cohen contributed equally as senior authors.

This work was supported by a grant from the Morris Animal Foundation, the Link Equine Research Endowment, and a gift from ALOPEXX Vaccines, LLC.

Declaration of Ethics

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

Conflict of Interest

Dr. Colette Cywes-Bentley has licensing and potential royalty income for monoclonal antibody to PNAG from Alopexx Pharmaceuticals LLC. Dr. Gerald Pier has licensing income, equity share, and potential royalty income from Alopexx Vaccines, LLC for vaccines to PNAG and monoclonal antibody to PNAG from Alopexx Pharmaceuticals, LLC. Dr. Noah Cohen has research support from Alopexx Vaccines, LLC.

Influence of the Respiratory Cycle on Caudal Vena Cava Diameter in Healthy Foals Less than One Month of Age: A Pilot Study

Melanie C. Tuplin, DVM*; Alfredo E. Romero, BS, DVM, DACVS; and Søren R. Boysen, DVM, DACVECC

This study suggests that it is possible to repeatably measure the caudal vena cava (CVC) sonographically in healthy foals, and the caudal vena cava collapsibility index (CVC-CI) may prove useful in assessing the intravascular volume status (IVS) in hypovolemic foals. Authors' address: Department of Veterinary Clinical and Diagnostic Sciences, Faculty of Veterinary Medicine, University of Calgary, 3280 Hospital Drive NW, Calgary, AB T2N 4Z6, Canada; e-mail: mtuplin@ucalgary.ca. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Intravascular volume status (IVS) assessment in foals is challenging. A technique in humans to measure the IVS uses the caudal vena cava collapsibility index (CVC-CI) defined as caudal vena cava (CVC) diameter at maximum expiration (CVC_{max}) – CVC diameter at minimal inspiration (CVC_{min}) / $CVC_{max} \times 100\%$. The objective of this study was to prospectively determine whether the CVC can be sonographically measured in healthy foals less than 1 month old. If measurable, the differences in CVC_{max} and CVC_{min} , and inter-rater variability between two examiners for CVC-CI will be assessed.

2. Material and Methods

The CVC was evaluated using a longitudinal subxiphoid window in 60 standing foals by one of two, or both observers. The CVC_{max} and CVC_{min} were statistically compared using a linear mixed model.

Inter-rater agreement was analyzed using Bland-Altman plots.

3. Results

CVC_{max} and CVC_{min} measurements (2.01 ± 0.47 , 1.49 ± 0.39 , respectively) were attained from 58/60 foals (age 15 ± 7.9 days; weight, 75.5 ± 17.7 kg). The CVC_{max} was significantly different from CVC_{min} ($D = 0.515$, $SE = 0.031$, $P < .01$). Inter-rater agreement of the CVC-CI differed by an average of -0.9% (95% limits of agreement, -12.5 to $+10.7\%$).

4. Discussion

There is significant difference between CVC_{max} and CVC_{min} showing similar changes in CVC diameter as described in human medicine. Inter-rater agreement shows no significant difference between two operators, suggesting that the technique is repeatable.

Research Abstract—for more information, contact the corresponding author. The full article is published in Tuplin MC, Romero AE, Boysen SR. Influence of the respiratory cycle on caudal vena cava diameter measured by sonography in healthy foals: A pilot study. *J Vet Intern Med* 2017. doi:10.1111/jvim.14793.

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Sources 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.

The Effect of Probiotic Use During a *Clostridium difficile* Diarrhea Outbreak in Neonatal Foals

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1. Introduction

The use of probiotic supplementation to modulate the gut microbiota may have the potential to significantly affect both human and animal health. Advances in understanding how oligosaccharides modulate this microbial community, especially with respect to gut pathogenesis and probiotic efficacy, show that this approach may be especially effective in nursing mammals if bacterial strains utilizing these oligosaccharides are used. The objective of this study was to test whether this approach, utilizing probiotic strains capable of utilizing mare milk oligosaccharides, could be successfully applied to help reduce *C. difficile*-associated diarrhea among neonatal foals.

2. Materials and Methods

Forty-one Thoroughbred foals were enrolled over the course of a single foaling season at a barn where an outbreak of *C. difficile* was identified. Foals were either dosed twice daily with *Bifido-*

bacterium longum subsp. *infantis* (3×10^{11} CFU) and *Lactobacillus plantarum* (1×10^9 CFU) during the first 2 days of life, or given the standard of care alone. Fecal samples were collected from birth through 14 days for 16S rDNA marker gene sequencing and quantitative polymerase chain reaction (qPCR).

3. Results

Among foals receiving the probiotic supplement, there was a significant reduction in incidence of *C. difficile*-associated diarrhea ($P < .0001$, Fisher's exact test). 16S rDNA marker gene sequencing and qPCR targeting *B. longum* subsp. *infantis* and *L. plantarum* found significant increases in *B. longum* subsp. *infantis* ($P < .001$, corrected *t*-test) in foals receiving the probiotic. Further, *B. longum* subsp. *infantis* was detected in significantly higher numbers in treated but not untreated animals at the end of the study, 12 days after their last supplementation. Supplemented foals also had a lower incidence of presumed *C. difficile*-associated diarrhea

Research Abstract—for more information, contact the corresponding author

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($P < .0001$, Fisher's exact test) and foal heat diarrhea during the 14-day study. ($P = .0284$, Fisher's exact test).

4. Discussion

Supplementation with a probiotic seemed to improve clinical observations of all diarrhea in nursing foals in the first 14 days of life after supplementation during an outbreak.

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

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Pharmacology of Antimicrobial Agents Used in Horses

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1. Introduction

Antibiotic therapy for horses has made many advances that have provided equine practitioners more options for treatment and accurate information to guide dose selection for the appropriate antibiotic regimen. Significant advances in pharmacokinetics, pharmacokinetics-pharmacodynamic (PK-PD) exposure relationships, and susceptibility testing are among the developments that have contributed to this knowledge. Although there are few (if any) new antibiotics approved for equine use in the past 20 years, we have learned to use the existing agents more effectively and learned more about extra-label drug uses from agents approved for people or other animal species. This discussion will review some of the important strategies for antibiotic use, PK-PD exposure relationships, and new advances in interpretation of susceptibility tests.

2. Activity of Antimicrobial Agents Against Common Bacteria

If the bacteria are accurately identified, antibiotic selection is simplified because the susceptibility pattern of many organisms is predictable. For example, if *Streptococcus equi* is identified, it is typically susceptible to penicillin, penicillin derivatives, and trimethoprim-sulfonamides. If *Pasteurella multocida*

is identified, it is also susceptible to most common antibiotics (penicillins, tetracyclines, trimethoprim-sulfonamides, cephalosporins). On the other hand, if *Staphylococcus* species are identified (methicillin-susceptible strains), they are often not susceptible to penicillin or tetracyclines, but should be susceptible to β -lactamase resistant β -lactams (e.g. a cephalosporin), fluoroquinolones, chloramphenicol, trimethoprim-sulfonamides, and a few other classes of agents. If anaerobic bacteria are suspected, such as *Clostridium*, *Peptostreptococcus*, *Actinomyces*, *Fusobacterium*, or *Bacteroides* (including those of the *Bacteroides fragilis* group), predictable results can be attained by administering penicillin and derivatives (ampicillin), chloramphenicol, metronidazole, and tetracyclines. (Not effective against anaerobes are aminoglycosides, most fluoroquinolones, and trimethoprim-sulfonamides.)

Gram-negative bacilli of the Enterobacteriaceae, and non-fermenters such as *Pseudomonas aeruginosa* represent bacteria frequently resistant to commonly used antibiotics. Susceptibility is not predictable and a susceptibility test is advised. These bacteria include *Pseudomonas aeruginosa*, Enterobacteriaceae (*E. coli*, *Klebsiella*, *Enterobacter*, *Proteus*).

Treatment for the gram-negative enteric bacterial infections can be initiated with a fluoroquinolone (e.g.

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Table 1. Tissue Barriers to Drug Diffusion

Tissue	Barrier	Drugs that will Penetrate
Brain	Blood-brain barrier	Fluoroquinolones (minimal), chloramphenicol (minimal), trimethoprim, third-generation cephalosporins (some), metronidazole
Eye	Blood-ocular barrier	Tetracyclines, fluoroquinolones, chloramphenicol
Respiratory tract	Blood-bronchus barrier (epithelial lining fluid)	Macrolides, tetracyclines, fluoroquinolones, chloramphenicol
Intracellular	Intracellular sites	Tetracyclines, azithromycin, fluoroquinolones

enrofloxacin), an extended-spectrum cephalosporin (ceftiofur), or an aminoglycoside (gentamicin, amikacin). However, if initial treatment is not effective, guidance from a susceptibility test is advised. For *Pseudomonas aeruginosa*, a susceptibility test is always advised.

3. Basic Pharmacokinetic Principles

The primary pharmacokinetic parameters of relevance to selecting doses for antimicrobial agents for horses are absorption, distribution, metabolism, and clearance. Oral absorption is more of a challenge in horses compared with people or small animals. Low oral absorption limits the use of this route to only a few drug classes. Studies on distribution allow predictions of where the drug will distribute to (or not), in order to predict effectiveness.

4. Penetration to the Site of Infection

For most tissues, antibiotic drug concentrations in the serum or plasma approximate the drug concentration in the extracellular space (interstitial fluid). This is because there is no barrier that impedes drug diffusion from the vascular compartment to extracellular tissue fluid.¹ There is really no such thing as “good penetration” and “poor penetration” when referring to most drugs in most tissues. Pores (fenestrations) or microchannels in the endothelium of capillaries are large enough to allow drug molecules to pass through unless the drug is restricted by protein binding in the blood. If adequate drug concentrations can be achieved in plasma, it is unlikely that a barrier in the tissue will prevent drug diffusion to the site of infection as long as the tissue has an adequate blood supply. Drug diffusion into an abscess or granulation tissue is sometimes a problem because in these conditions, drug penetration relies on simple diffusion and these sites of infection lacks adequate blood supply.

In some tissues, a lipid membrane (such as tight junctions on capillaries) presents a barrier to drug diffusion (Table 1). In these instances, a drug must be sufficiently lipid soluble, or be actively carried across the membrane in order to reach effective concentrations in tissues. These tissues include the central nervous system, eye, and prostate. A functional membrane pump (p-glycoprotein) also contributes to the barrier. There also is a barrier between

plasma and bronchial epithelium (blood:bronchus barrier). This limits drug concentrations of some drugs in the bronchial secretions and epithelial fluid of the airways. Lipophilic drugs may be more likely to diffuse through the blood-bronchus barrier and reach effective drug concentrations in bronchial secretions.

5. Local Factors that Affect Antibiotic Effectiveness

Local tissue factors may decrease antimicrobial effectiveness. For example, pus and necrotic debris may bind and inactivate vancomycin or aminoglycoside antibiotics (gentamicin or amikacin), causing them to be ineffective. Cellular material also can decrease the activity of topical agents such as polymyxin B. Foreign material in a wound (such as material surgically implanted) can protect bacteria from antibiotics and phagocytosis by forming a biofilm (glycocalyx) at the site of infection. Cellular debris and infected tissue can inhibit the action of trimethoprim-sulfonamide combinations through the secretion of thymidine and PABA, both known to be inhibitors of the action of these drugs. This may explain why trimethoprim-sulfonamide combinations have not been effective in some infected tissues. Cations can adversely affect the activity of antimicrobials at the site of infection. Two important drug groups diminished in activity by cations such as Mg^{++} , Al^{+3} , Fe^{+3} , and Ca^{++} are fluoroquinolones and aminoglycosides. (Cations such as magnesium, iron, and aluminum also can inhibit oral absorption of fluoroquinolones.)

An acidic environment of infected tissue may decrease the effectiveness of clindamycin, erythromycin, fluoroquinolones, and aminoglycosides. An anaerobic environment decreases the effectiveness of aminoglycosides because oxygen is necessary for drug penetration into bacteria. As mentioned previously, an adequate blood flow is necessary to deliver an antibiotic to the site of infection. Effective antibacterial drug concentrations may not be attained in tissues that are poorly vascularized (e.g. extremities during shock, sequestered bone fragments, and endocardial valves).

6. PK-PD Optimization of Doses

To achieve a cure, the drug concentration in plasma, serum, or tissue fluid should be maintained above

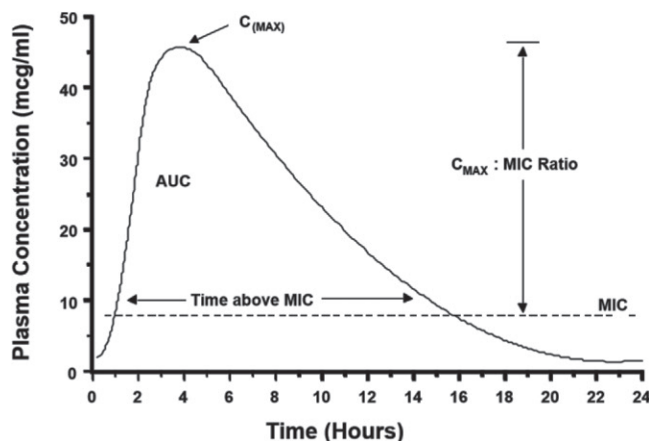


Fig. 1. Pharmacokinetic-Pharmacodynamic (PK-PD) parameters shown in relation to the MIC for a typical plasma concentration vs. time profile.

the minimum inhibitory concentration (MIC), or some multiple of the MIC, for at least a portion of the dose interval. PK-PD relationships of antibiotics explain how these factors can correlate with clinical outcome.² The parameters that define antibacterial activity are taken from the shape of the plasma concentration vs time profile. The C_{MAX} is simply the maximum plasma concentration attained during a dosing interval. The C_{MAX} is related to the MIC by the $C_{MAX}:MIC$ ratio. The AUC is the total area under the curve. The AUC for a 24-hour period is related to the MIC value by the AUC:MIC ratio. The time-above-MIC is the relationship of time to MIC measured in hours ($T > MIC$; Fig. 1).

Rather than consider a drug as simply bacteriostatic or bactericidal, it is more useful to categorize drugs as either concentration dependent or time dependent in its action. If concentration dependent, one should administer a high enough dose to maximize the $C_{MAX}:MIC$ ratio or AUC:MIC ratio. If time dependent, the drug should be administered frequently enough to maximize the $T > MIC$.

Examples of how these relationships affect drug regimens are described below:

Aminoglycosides

Aminoglycosides (e.g. gentamicin, or amikacin) are concentration-dependent bactericidal drugs; therefore, the higher the drug concentration, the greater the bactericidal effect. This property is more important for gram-negative bacilli than gram-positive cocci. An optimal bactericidal effect occurs if a high enough dose is administered to produce a peak of 8 to 10 times the MIC. This can be accomplished by administering a single dose once daily.³ This regimen can be more effective and less nephrotoxic than lower doses administered more frequently. The current regimens in horses employ this strategy.

Fluoroquinolones

For the fluoroquinolone antimicrobials, as reviewed by Wright⁴ and others, investigators have shown that either the peak plasma concentration above bacterial MIC, also known as the $C_{MAX}:MIC$ ratio, or the total AUC above the MIC (also known as the AUC:MIC ratio), may predict clinical cure in studies of laboratory animals, and in a limited number of human clinical studies. There are no published studies involving horses that indicate which of these parameters are the best predictor of clinical cure, or what the respective target ratios might be. Therefore, the optimum value for these surrogate markers has not been determined for infections in horses. However, derived from other studies, a $C_{MAX}:MIC$ of 8 to 10, or a AUC:MIC of 75 to 100 have been associated with a cure. As reviewed by Wright,⁴ for some clinical situations AUC:MIC ratios as low as 30 to 55 for a clinical cure.

Beta-lactam Antibiotics

β -lactam antibiotics such as penicillins, potentiated-aminopenicillins, and cephalosporins are bactericidal but the process is slow and time dependent.

Their concentration should be kept above the MIC throughout most of the dosing interval (long $T > MIC$) for the optimal bactericidal effect.⁵ Dosage regimens for the β -lactam antibiotics should consider these PD relationships. To avoid the need for frequent injections, some long-acting formulations have been developed to prolong plasma concentrations (e.g. ceftiofur^a). Gram-positive organisms are more susceptible to the β -lactams than are gram-negative bacteria and lower doses and longer intervals are possible when treating these bacteria. Additionally, because antibacterial effects occur at concentrations below the MIC (post antibiotic effect) for *Staphylococcus*, longer dose intervals may be possible for staphylococcal infections.

Other Time-Dependent Drugs

The drugs such as tetracyclines, macrolides (erythromycin and derivatives), sulfonamides, lincosamides (lincomycin and clindamycin), and chloramphenicol derivatives act in a time-dependent manner against most bacteria. Either time above MIC ($T > MIC$) or total drug exposure, measured as AUC/MIC, has been used to predict clinical success for these drugs.

The time-dependent activity is demonstrated by studies in which effectiveness is highest when the drug concentrations are maintained above the MIC throughout the dosing interval. Drugs in this group should be administered frequently to achieve this goal. However, a property of some is that they persist in tissues for a prolonged time, which allows infrequent dosing intervals. The macrolide derivative azithromycin^b has a long tissue half-life and long persistence in leukocytes to permit infrequent dosing. Most published dosage regimens are designed to take the PK properties of these drugs into account.

7. Application of Antibiotic Pharmacology Principles to Susceptibility Testing

Empirical treatment of common infections in animals can be accomplished by selecting the antimicrobial agent with a high likelihood of success for the suspected clinical infection. Many guidelines have appeared in published proceedings, review papers, consensus documents, and textbooks. But when empirical treatment fails, or when resistance is suspected, a culture and susceptibility test is needed to guide therapy.

Culture and antimicrobial susceptibility testing (AST) will provide the best guidance for drug selection. However, it is also understood that even when an agent is selected from the “susceptible” category, treatment may not always be successful. The prediction of whether the bacteria will, or will not respond to treatment is commonly referred to as the “90/60 rule.”⁶ The 90/60 rule was derived from the observation that, in general, bacteria treated with antimicrobials to which the strain is susceptible will have a favorable therapeutic response in approximately 90% of the patients. On the other hand, when the bacteria are resistant to the antimicrobial administered, despite the susceptibility result, approximately 60% of patients will respond to therapy. In veterinary medicine, we have no data to confirm or challenge the 90/60 rule.

The most important information for the clinician is simply which drugs have an “S” and which ones have an “R.” These results then guide their treatment. What really goes into this interpretation? The standards for interpretation are available from the Clinical and Laboratory Standards Institute (CLSI)^{7,8} (found at <http://www.clsi.org/>). Not all laboratories use CLSI standards. It is a voluntary program. However, it is the only global organization that develops susceptibility testing standards for animals. If a laboratory does not adhere to a public standard such as CLSI, breakpoints may vary and interpretation may be inconsistent from laboratory to laboratory.

Microdilution Test for Determination of MIC

It is becoming more common for laboratories to directly measure the MIC of an organism with an antimicrobial dilution test. Zone inhibition (also known as the Kirby-Bauer test) also is performed but provides only qualitative information. The MIC dilution test is performed by inoculating the wells of a plate with the bacterial culture and dilutions of antibiotics are arranged across the rows. The test is usually performed in modern laboratories using high-throughput plates, but individual tubes or plates can be used for dilution tests also. Antibiotic drug concentrations are arranged in serial dilutions, with each concentration doubled from lowest to highest in a range. The MIC is not a measure of efficacy, but instead it is simply an *in vitro* measurement of drug activity and bacterial susceptibility. The lower the MIC value, the more susceptible

the isolate is to that drug. The MICs are determined using serial 2-fold dilutions (Log_2) of drug to which is added a standardized inoculum that is incubated for a prescribed time. Concentrations are always listed in $\mu\text{g/mL}$ (mg/L). For example, if one were to start at a concentration of 256 $\mu\text{g/mL}$, the MIC dilution series would be as follows: 128, 64, 32, 16, 8, 4, 2, 1, 0.5, 0.25, 0.12, and 0.06 $\mu\text{g/mL}$, etc. If, for example, bacterial growth occurs at a dilution of 0.12 $\mu\text{g/mL}$ for a specific drug, but not at 0.25 $\mu\text{g/mL}$ and above, the MIC is determined to be 0.25 $\mu\text{g/mL}$. The MIC dilution test is only semi-quantitative because there are gaps between each dilution. Realistically, the true MIC lies somewhere between these values, but the MIC is recorded as the lowest concentration that inhibits growth.

Interpretation of Susceptibility Tests

Resistance and susceptibility are determined by comparing the organism’s MIC to the drug’s breakpoint as established by the Clinical and Laboratory Standards Institute.^{7,8} After a laboratory determines a MIC, it may use the CLSI “SIR” interpretive categories: S, susceptible; I, intermediate, or R, resistant. In practice, if the MIC for the bacterial isolate falls in the susceptible category, there is a greater likelihood of successful treatment (cure) than if the isolate were classified as resistant. It does not assure success; drug failure is still possible owing to other drug or patient factors (for example, immune status, immaturity, or severe illness that compromises the action of antibacterial drugs), and interactions. If the MIC is in the resistant category, bacteriologic failure is more likely because of specific resistance mechanisms or inadequate drug concentrations in the patient. However, a patient with a competent immune system may sometimes eradicate an infection even when the isolate is resistant to the drug in the MIC test.

The intermediate category is intended as a buffer zone between susceptible and resistant strains. This category reflects the possibility of error when an isolate has a MIC that borders between susceptible and resistant. If the MIC value is in the intermediate category, therapy with this drug at the usual standard dosage is discouraged because there is a good likelihood that drug concentrations may be inadequate for a cure. However, successful therapy is possible when drug concentrates at certain sites—in urine, or as the result of topical therapy, for example—or at doses higher than the minimum effective dose listed on the label. For example, prescribing guidelines for some antimicrobials allow for an increase in dose when susceptibility testing identifies an organism in the intermediate range of susceptibility.

MIC data should not be used in isolation, but by coupling the MIC from a laboratory report with CLSI breakpoints and other important information such as the virulence of the bacteria and the pharmacology of the antibiotics being considered, the

clinician can make a more informed selection of an antibacterial drug.

Does the Susceptibility Test Provide Tissue-Specific Interpretation?

The susceptibility interpretation is based on plasma/serum concentrations. No tissue-specific interpretation can be provided that accounts for differences in drug distribution among tissues (exception for urine isolates for some agents). A frequent mistake in MIC interpretation is to compare the MIC with published tissue concentrations that are derived from whole-tissue homogenized samples. Tissue concentration data are often published by pharmaceutical companies in their product information.

Tissue concentrations may be misleading because they may either underestimate or overestimate (depending on the drug's affinity for intracellular sites) the true drug concentration at the site of infection.

In most instances the clinician should not be concerned with the question of whether or not there are tissue-specific susceptibility interpretations. As discussed above, for most tissues, antibiotic drug concentrations in the serum or plasma approximate the drug concentration in the extracellular space (interstitial fluid). If adequate drug concentrations can be achieved in plasma, it is unlikely that a barrier in the tissue will prevent drug diffusion to the site of infection as long as the tissue has an adequate blood supply.

Is Susceptibility Interpretation by CLSI Specific for Veterinary Species?

In past years, the veterinary diagnostic laboratories had to rely heavily on the CLSI interpretation from the human standards. There were not enough veterinary-specific breakpoints in the interpretive categories available for veterinary drugs and veterinary species. This is now changing. The current edition of the CLSI standard document^{7,8} for veterinary drugs has the tables clearly separated into those drugs with veterinary interpretive criteria, and drugs that still rely on human standards for interpretation. In the last several years, CLSI has tremendously expanded the list of drugs for which there are veterinary-specific breakpoints. There are now equine-specific breakpoints for amikacin, gentamicin, doxycycline, enrofloxacin, ampicillin, cefazolin, ceftiofur, and penicillin.

Until veterinary-specific breakpoints are established for other antibiotics used in horses, we will continue to rely on the human breakpoints for drugs such as chloramphenicol, erythromycin, carbapenems (imipenem), some penicillins, sulfonamides, and potentiated sulfonamides. The CLSI committee is working on filling in these gaps.

How Are Breakpoints Derived?

The paper by Turnidge and Paterson⁹ describes in detail the process of setting breakpoints. The CLSI

subcommittee for Veterinary Antimicrobial Susceptibility Testing (VAST), uses strict criteria to establish and evaluate breakpoints. Sponsors are required to follow guidelines provided by CLSI and must submit data to support a proposed breakpoint. The data includes PK data in the target species, MIC distributions for the pathogens targeted, clinical data from the drug used under field conditions at the approved dose, and PK-PD analysis, using Monte Carlo simulations¹⁰ to show that at the approved dose the drug attains PK-PD targets for the labeled pathogen.²

Are These Standards or Guidelines?

The CLSI is a consensus-driven process and after approval by the subcommittee the standards become public documents. The consensus process involves the development and review of documents, revision of documents in response to discussion, and, finally, the acceptance of a document as a consensus standard or guideline. The CLSI documents used for culture and susceptibility testing should be regarded as a public standard, not a guideline.

A Standard is a document developed through the consensus process that clearly identifies specific, essential requirements for materials, methods, or practices for use in an unmodified form. A *Standard* may, in addition, contain discretionary elements, which are clearly identified. A *Guideline* is a document developed through the consensus process describing criteria for a general operating practice, procedure, or material for voluntary use. A *Guideline* may be used as written or modified by the user to fit specific needs.

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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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Hot Topics in Antimicrobial Resistance

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1. Introduction

The discovery and subsequent ready availability of antimicrobials revolutionized human and veterinary medicine; however, the parallel emergence and dissemination of antimicrobial resistance compromise these gains. Bacterial pathogens have demonstrated an impressive ability to become resistant to an array of antimicrobials, sometimes surpassing the ability to create new drugs. Resistance of any pathogen to any antimicrobial can be a clinically important event, but certain bacterium-resistance combinations are of particular concern because of the potential for broad effect on animal (and sometimes human) health.

2. The Relevance of Antimicrobial Resistance

It is useful to consider what antimicrobial resistance means from microbiological and clinical standpoints. Resistance simply means that a bacterium has an inherent or acquired ability to evade inhibition or killing by an antimicrobial. This does not necessarily mean there is any difference in ability to cause disease, likelihood of causing severe disease, or other clinically relevant factors. Antimicrobial resistance in itself is not a virulence factor. However, resistance can affect clinical outcome. It is important to note that beyond the need for a different drug, the overall approach to resistant infections does not differ from infections caused by susceptible

pathogens. This highlights the importance of prompt identification of resistant infections, so that proper treatment can be initiated. Similarly, if an antimicrobial susceptible pathogen would be dismissed as irrelevant based on a culture result, the same approach is almost always indicated for a resistant pathogen. Treatment decisions, both whether to treat and what to do in addition to antimicrobials, are not inherently different in infections caused by resistant vs susceptible bacteria. Concerns about untreatable infections caused by bacteria that are resistant to all available antimicrobials continue to increase, and are approaching reality in human medicine. The same degree of resistance is not typically identified in equine pathogens; however, the limited number of drugs that can be safely and effectively used in horses means that infections with few viable options may be encountered. Yet, it is important to remember that the vast majority of infections are treatable with routinely used drugs, and there is almost always a viable antimicrobial option. The key aspect, and one that cannot be overemphasized, is the need for early recognition of resistant infections so that proper treatment can be initiated. Although resistant pathogens are no more inherently virulent than their susceptible counterparts, empirical treatment using ineffective drugs can certainly worsen the prognosis. In essence, horses do not die or have poor outcomes from

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antibiotic resistance, those occur because of an untreated disease process. Antimicrobial resistance increases the likelihood that initial antimicrobials are ineffective, highlighting the value of prompt and effective diagnostic testing.

3. Notable Antimicrobial Resistant Pathogens

Although antimicrobial resistance of some form may be present in virtually any bacterial species, the main effect of resistance comes from a relatively limited number of bacteria. These tend to be bacteria that commonly cause opportunistic infections and that are often present as part of the commensal microbiota. Those properties mean that there can be abundant exposure to antimicrobials over time, and that resistant forms can spread silently in the healthy horse population.

Staphylococci

Staphylococci are classical opportunistic pathogens that are particularly adept at causing skin and skin structure infections. From the first emergence of penicillin resistance shortly after the discovery of penicillin to identification of virtually pan resistant strains in humans, staphylococci have created substantial clinical challenges. The emergence of methicillin-resistant (MR) staphylococci, particularly *S. aureus* (MRSA), as important veterinary pathogens in the 1990s and 2000s, ushered in a new era of concern about difficult-to-treat and zoonotic infections. Staphylococci are common mucosal colonizers, and most (if not all) horses harbor one or more *Staphylococcus* at any time. Methicillin resistance is not uncommonly found in staphylococci from healthy horses, predominantly in minimally virulent coagulase-negative staphylococci but occasionally in *S. aureus* (a coagulase-positive species). MRSA can be found in the nasal passages, oropharynx, or gastrointestinal tract of a small percentage of horses, with most reports describing prevalences of 0% to 5% in the general horse population.¹⁻⁵ Higher rates can be found in certain populations, such as hospitalized horses.^{1,6,7} While antimicrobial exposure and hospitalization are risk factors for MRSA shedding,^{1,8} MRSA can be isolated from horses in the absence of known exposure or risk factors. MRSA colonization can be found in horses internationally, although the relative strain distribution tends to vary. In North America, MRSA strains found in horses are typically human clones, particularly USA500 (an uncommon human strain that may be horse adapted) and USA100 (the leading MRSA strain in human healthcare facilities in the United States).^{5,9,10} In contrast, the livestock associated sequence type 398 clone tends to predominate in Europe.¹¹⁻¹⁴ A rarer variant of MRSA containing a different (and more-difficult-to-detect) methicillin-resistance gene, *mecC*, has been identified in a small number of European horses.¹⁵

In horses, skin and wound infections (including surgical site infections) along with infections associ-

ated with joint injections are the most commonly encountered staphylococcal infections, with *S. aureus* being the main species involved. The canine-origin *S. pseudintermedius*, including its MR variant Methicillin-resistant *Staphylococcus pseudintermedius* (MRSP), are occasionally identified in equine infections.¹⁶⁻¹⁸ A wide range of other staphylococci, predominantly coagulase-negative species, can be isolated from clinical infections. However, this group of staphylococci is commonly found on the skin and tends to be of limited virulence. Therefore, coagulase-negative staphylococci are often present as commensals or contaminants, rather than causes of disease. This is important to differentiate because coagulase-negative staphylococci are often multidrug resistant, and it is important to determine whether they need to be targeted or ignored clinically.

Most MRSA isolates found in horses are susceptible to one or more drugs that can be used in horses, such as aminoglycosides or chloramphenicol. Although sometimes undesirable, these drugs can be effective, and drug selection for MRSA infections must consider the susceptibility profile of the isolate, the location of infection, and issues relating to the different drug options (e.g., safety, penetration, route of administration). Limited systemic options highlight the potential usefulness of local therapy. This can include topical therapy for skin and superficial soft-tissue infections (e.g., chlorhexidine, mupirocin, silver sulfadiazine), regional limb perfusion, intra-articular injection (e.g., amikacin) and implantation or injection of antimicrobial-impregnated materials (e.g., polymethylmethacrylate beads, gel matrices). These can deliver high local concentrations, sometimes for sustained periods, with limited systemic exposure.

Pseudomonas

Pseudomonas is a genus of gram-negative bacteria that thrives in moist environments, both on and off the host. As with staphylococci, *Pseudomonas* infections are almost always (if not always) in response to an underlying disease process, with wound infections being a common manifestation of *Pseudomonas* in horses. *Pseudomonas* infections can be challenging to treat for many reasons. *Pseudomonas* spp. are intrinsically resistant to many antimicrobials (e.g., most penicillins and cephalosporins) and often acquire further resistance. Susceptibility to anti-pseudomonal cephalosporins (e.g., ceftazidime) and aminoglycosides remains high,^{19,20} although resistance to either can be found and this may vary geographically. Fluoroquinolone resistance is relatively common^{19,21-23} and can develop quickly during monotherapy. Combination therapy is often used when treating *Pseudomonas* infections in humans, both for synergistic effects and to reduce the likelihood of emergence of resistance. This is less commonly used in horses, probably

mainly because of cost rather than lack of need, but should be considered when parenteral treatment is needed. *Pseudomonas* also tend to be heavy biofilm producers, and biofilm can inhibit the activity of antimicrobials and the immune response, leading to poor response despite *in vitro* antimicrobial susceptibility.

Topical therapy for superficial infections can be useful to overcome resistance, allow for the use of antimicrobials that are not safe to use systemically (e.g., polymixin B) or avoid the need for systemic drugs. Topical therapy can involve biocides (e.g., chlorhexidine) or antimicrobials (e.g., polymixin, gentamicin). Resistance to both can be present but clinically relevant resistance to the concentrations that can be delivered locally is rare. Adjunctive therapies, such as the use of Tris-ethylenediaminetetraacetic acid (EDTA) to enhance antibacterial effects^{24,25} may be useful locally. Another aspect of note about *Pseudomonas* is its ability to survive in water, be resistant to some disinfectants and be a source of hospital- and equipment-associated infections.

Enterobacteriaceae

Enterobacteriaceae is a family of Gram-negative bacteria that includes animal and human pathogens such as *E. coli*, *Enterobacter*, *Proteus*, *Salmonella*, and *Klebsiella*. These bacteria can be involved in a variety of infections, and antimicrobial resistance is of increasing concern. Multidrug-resistant Enterobacteriaceae might represent the most dramatic and important shift in resistance patterns in horses during the past few years. A few different types of resistance, mediated by a wide (and sometimes confusing) collection of resistance genes, can be involved.

Beta-lactamase production is common among Enterobacteriaceae and confers resistance to penicillins (e.g., ampicillin, amoxicillin) but not cephalosporins. It can often be controlled through the addition of a beta-lactamase inhibitor (e.g., sulbactam). Beta-lactamase-producing Enterobacteriaceae are well known and widely disseminated.

Extended-spectrum beta-lactamases (ESBLs) are enzymes that confer a broader degree of resistance. ESBLs are effective against extended-spectrum cephalosporins (e.g., ceftiofur, cefotaxime, ceftazidime) and monobactams (e.g., aztreonam) but are ineffective against cephamycins (e.g., cefoxitin) and carbapenems (e.g., meropenem). They are inhibited by beta-lactamase inhibitors such as clavulanic acid or sulbactam although clinical response to beta-lactam/beta-lactamase inhibitor combinations can be unpredictable. ESBL-producing bacteria are disseminated widely in humans in a highly diverse population of Enterobacteriaceae, and are significant causes of disease, particularly in hospitals and long-term care facilities. Although currently less of a concern than in humans, ESBLs are increasingly being identified in horses, both in equine hospitals and on farms. The ongoing emergence of ESBLs

may represent a greater threat to horses than the higher-profile emergence of MRSA in the horse population. The emergence of ESBLs may be both a result of emergence of resistance in the horse population and transmission of resistant strains from humans, given that the same ESBL-containing bacteria have been found in both humans and horses.^{26,27}

ESBL-producing bacteria cause the same types of infections as their susceptible counterparts, such as wound infections, neonatal sepsis, pneumonia, and urinary tract infection. Because ESBL-producing bacteria tend to be species that are common gut commensals, accumulation of ESBLs in the gut of healthy horses and dissemination throughout the horse population is a concern. Surveillance studies have identified highly concerning ESBL prevalence rates in some populations, such as a study that found ESBLs in 84% of horses at an equine clinic in The Netherlands.²⁸ Reports from only a few years prior in other countries identified much lower rates (e.g., 6.3% in the United Kingdom).³ Whether that represents marked geographic variation or a profound increase in a short period of time is unknown, but it is hard to deny that ESBLs are more frequently identified in horses internationally. A retrospective study of *E. coli* isolates from horses in Switzerland reported an ESBL prevalence of 60%,²⁹ with even higher rates noted elsewhere,³⁰ highlighting the potential clinical challenges. Antimicrobial exposure has been shown to increase the risk of ESBL shedding^{3,31}; however, fecal shedding can be detected in the absence of known antimicrobial exposure or hospitalization, as is also the case with MRSA.

Management of infections caused by ESBL producing bacteria can be complicated because of limited drug options. Antimicrobial options depend on susceptibility to other antimicrobials as ESBL-producing bacteria have often also acquired resistance to other antimicrobials (e.g., fluoroquinolones).³² Cefoxitin (a cefamycin, not a cephalosporin) can be an effective option in some situations; however, response to this antimicrobial can be unpredictable. Dosing regimens (route and frequency) are also problematic for outpatients. Beta-lactam/beta-lactamase inhibitor (e.g., beta-lactam with clavulanic acid, sulbactam, and tazobactam) combinations may be effective, but that depends on the amount of ESBL production, as high production of ESBLs (especially when more than one gene is involved) can overwhelm the beta-lactamase inhibitor. Amikacin and carbapenems are often the main viable choices, both of which can be clinically effective but are often undesirable because of factors such as the need for parenteral injection, toxicity, and for carbapenems, their importance in human medicine. Some isolates may be susceptible to other drug classes that have activity against Gram-negative bacteria (e.g., tetracyclines, chloramphenicol, trimethoprim-sulfa) but often ESBL-producing bacteria have concur-

rently acquired resistance to many or all of these other classes.

The similarity of some ESBL genes and ESBL-producing bacteria found in humans and horses indicates that human–animal transmission may be an important route of infection of veterinary patients, but also indicates that there must be concern about the potential for zoonotic transmission from infected or colonized animals, although the true role of animals in human infections is not known.

Similar to (and sometimes confused with) ESBLs, AmpC (CMY-2) beta-lactamases confer resistance to penicillins and cephalosporins, but in addition they confer resistance to cephamycins such as ceftiofur. They are also resistant to beta-lactamase inhibitors. Carbapenems or aminoglycosides tend to be the main options for treatment of infected horses, although as with ESBLs, other drugs such as trimethoprim-sulfa, doxycycline, chloramphenicol, and fluoroquinolones may be effective in some situations. Antimicrobial susceptibility testing results are needed to guide effective therapy.

Carbapenems are uncommonly used in horses, and mainly in neonatal intensive care units. Emergence of carbapenemase-producing Enterobacteriaceae (CPE) is a critically important emerging issue in human health care. Carbapenemases are a diverse group of enzymes with variable efficacy against carbapenems (e.g., meropenem) as well as most other beta-lactams. They confer resistance to penicillins, carbapenems, and, depending on the gene that is involved, potentially all cephalosporins, and therefore have a broad range of resistance that is often complemented with acquired resistance to various other drug classes. The effect of beta-lactamase inhibitors is variable and often weak, leading to CPE infections where there may be few viable treatment options. There are only rare reports of CPE in animals^{30,33} but CPE have been identified in a horse in Europe,³⁰ with anecdotal reports on infections in horses in North America. This may relate to “spillover” from humans, with CPE in animals reflecting movement of CPE into humans in the community, but that has yet to be confirmed.

Although CPEs constitute a critically important human health care issue, they are not the “ultimate superbug.” In the past few years, Enterobacteriaceae resistant to almost all, or all, antimicrobials have been identified, with particular emphasis on the emergence of colistin resistance.^{34,35} These have also been found in animals, including companion animals,³⁶ and although these highly resistant pathogens are unlikely to become important equine pathogens, the potential role of animals as reservoirs and sources of human infection is of much concern.

From a more common and clinically important standpoint, fluoroquinolone resistance continues to be a problem. Fluoroquinolones can be excellent drugs against Gram-negative pathogens but resis-

tance can emerge through various mechanisms, including mutation (e.g., mutations in DNA gyrase or topoisomerase IV genes) or acquisition of genes (e.g., those that decrease drug uptake or mediate efflux pumps). Single-step mutations may have variable effects on bacterial minimum inhibitory concentrations (MICs), ranging from subtle changes in MIC with continued susceptibility to resistance. Accumulation of multiple mutations is most often associated with clinical resistance, with resistance to one fluoroquinolone typically meaning that resistance is present to all fluoroquinolones (albeit there is some potential variability between drugs, with MICs often being lower to newer fluoroquinolones).³⁷

Enterococcus

This genus includes a variety of species of varying clinical relevance. Most infections are caused by two species, *E. faecium* and *E. faecalis*, both of which can often be associated with multidrug resistance. Enterococci are inherently resistant to a variety of drug classes (e.g., penicillin, trimethoprim), some drug classes have poor efficacy *in vivo* (e.g., cephalosporins, fluoroquinolones) and acquisition of resistance genes is not uncommon. Therefore, they are at best potentially susceptible to only a limited range of “routine” veterinary drugs, and multidrug resistance is not uncommon. Enterococci resistant to all routinely tested drugs are not unusual and pose challenges.

Yet, despite the commonness of antimicrobial resistance, enterococci tend to be of limited virulence. A major challenge in dealing with cultures yielding enterococci is determining the clinical relevance. Enterococci can cause opportunistic infections such as wound infections and neonatal sepsis.^{38,39} However, they are often present as contaminants, commensals, or co-infections, and isolation of an *Enterococcus* from an infected site does not always mean that treatment is needed. That is particularly true when an *Enterococcus* is isolated alongside a more convincing pathogen (e.g., *S. aureus*, Enterobacteriaceae) and treatment of the other organism will often result in clinical cure. Thus, deciding whether to treat an *Enterococcus*, particularly a highly drug-resistant isolate that may require an undesirable drug, is an important factor.

Others

Antimicrobial resistance is not restricted to the above-described groups. Some, such as *Serratia* and *Acinetobacter*, are commonly multidrug resistant. These are uncommon causes of infection, but can be difficult to treat. Virtually any clinically relevant bacterium can be resistant to antimicrobials, and on the individual patient level, that resistance may range from innocuous to life threatening, largely based on the severity of disease, rapidity of identification of resistance, and time to start of appropriate therapy. However, in contrast, antimicrobial resistance is rare in the very common equine pathogen *Streptococcus equi*

subsp. *zooepidemicus*,^{40–42} despite the widespread presence of this bacterium and frequent antimicrobial exposure. Why resistance has developed so widely to *S. aureus* but not *S. zooepidemicus*, bacteria that are both common mucosal commensals and widely dispersed in the horse population internationally, is enigmatic, and is one of many interesting and unanswered questions.

4. Conclusions

Antimicrobial resistance is a problem that will continue to challenge veterinarians and antimicrobial use in veterinary medicine will continue to come under scrutiny. Although currently limited in veterinary medicine, efforts to move toward a broader “antimicrobial stewardship program” approach are becoming prominent in human medicine and bear consideration for equine medicine. This includes various approaches to optimize (not just restrict) antimicrobial use and is beyond the scope of this discussion. However, basic aspects such as ensuring prompt collection of culture specimens whenever possible, collecting samples from appropriate sites to reduce the risk of contamination, use of a laboratory that follows standardized testing and reporting guidelines, scrutinizing culture results to identify potential contaminants or spurious results, using resources to ensure proper dosing regimens and remembering to assess the patient as a whole, not just the laboratory result, are practical yet important measures to optimize treatment of bacterial infections.

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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Antimicrobial Therapy of Infections Caused by *Rhodococcus equi* in Foals

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1. Introduction

Rhodococcus equi, a Gram-positive facultative intracellular pathogen replicating in macrophages, is one of the most important causes of disease in foals between 3 weeks and 6 months of age, with most foals showing clinical signs before the age of 4 months. The most common manifestation of *R. equi* infections in foals is a chronic suppurative bronchopneumonia with extensive abscessation. The slow spread of the lung infection combined with the remarkable ability of foals to compensate for the progressive loss of functional lung, make early clinical diagnosis difficult. Early clinical signs often only consist of a mild fever or a slight increase in respiratory rate that may not be apparent unless foals are exercised or stressed by handling. As the disease progresses, clinical signs may include decreased appetite, lethargy, cough, fever, tachypnea, and labored breathing. Nasal discharge is an inconsistent finding. Because ultrasonographic screening for early detection has become routine practice at many farms endemic for pneumonia caused by *R. equi*, the most frequently recognized form of *R. equi* infection on those farms is a subclinical form in which foals develop sonographic evidence of peripheral pulmonary consolidation or abscessation without manifesting clinical signs.^{1,2} *R. equi* can also be cultured from a

large variety of extrapulmonary sites of infection. Extrapulmonary disorders might occur concurrent with or independent of pneumonia, and some foals have multiple extrapulmonary disorders concurrently.^{3,4} This article reviews recent data documenting spontaneous resolution of pulmonary lesions in a high proportion of subclinically affected foals and addresses current controversies in the treatment of infections caused by *R. equi*.

2. Not All Foals with Subclinical Pulmonary Lesions Need to be Treated

Over the past 17 years, control of *R. equi* infections at many farms where the disease is endemic has relied on early detection of subclinical pulmonary disease using thoracic ultrasonography and initiation of treatment with antimicrobial agents prior to development of clinical signs.^{1,2,5} The rationale for screening is the assumption that detecting foals in the early stages of disease along with appropriate treatment of affected foals will improve outcome. Although controlled studies are lacking, periodic ultrasonography of the chest seems to have decreased mortality due to *R. equi* pneumonia at some farms relative to historical controls.^{1,2,5} However, ultrasonographic screening has resulted in an increased number of foals treated for presumptive *R. equi*

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pneumonia. The temporal association between this widespread use of macrolides and rifampin because of ultrasonographic screening and a perceived increase in the frequency of detection of resistant isolates in the last decade⁶ suggest that this practice might not be innocuous. Emergence of widespread macrolide- and rifampin-resistance at a farm after widespread use of these drugs was instituted as part of an ultrasonographic screening program has been documented.⁷

Recent controlled studies have documented that approximately 70% to 88% of foals with small pulmonary lesions (sum of lesion diameters [or lesion score] of 1 to 10 cm) recover without antimicrobial therapy.⁸⁻¹⁰ In addition, antimicrobial treatment of foals with such small ultrasonographic lesions does not significantly hasten lesion resolution compared with administration of a placebo.^{8,9} In contrast, studies performed at the same farm documented that treatment of foals with lesion scores >10 cm provides a significant benefit relative to administration of a placebo.^{11,12} Additional studies are needed to establish better criteria to determine the need for therapy in subclinically affected foals and to better quantify the risks vs benefits of treating foals with subclinical ultrasonographic lesions.

3. The Combination of a Macrolide with Rifampin Remains the Treatment of Choice for Clinically Affected Foals

A wide variety of antimicrobial agents are active against *R. equi in vitro*. However, because *R. equi* is a facultative intracellular pathogen surviving and replicating in macrophages and therefore causes granulomatous lesions with thick caseous material, many of these drugs are believed to be ineffective *in vivo*. The combination of rifampin and erythromycin became the treatment of choice in the 1980s and has reduced foal mortality relative to historical data since its introduction. In recent years, clarithromycin or azithromycin, two newer-generation macrolides, often replace erythromycin in the combination with rifampin. Macrolides and rifampin are highly active against *R. equi in vitro* but only exert bacteriostatic activity. Of the three macrolides listed above clarithromycin is the most active against *R. equi in vitro*. The combination of a macrolide and rifampin is synergistic both *in vitro* and *in vivo*¹³⁻¹⁵ and the use of the two classes of drugs in combination reduces the likelihood of *R. equi* resistance to either drug.

Recent studies demonstrate that concurrent therapy with rifampin considerably decreases plasma, pulmonary epithelial lining fluid, and bronchoalveolar cell concentrations of clarithromycin and possibly other macrolides most likely through inhibition of intestinal-uptake transporters.^{16,17} These findings have led many to question the value of the combination. A well-designed, large-scale blinded clinical trial is needed to determine the benefit (or detriment) of combining a macrolide with rifampin for treating

foals with severe *R. equi* pneumonia. However, such a study is unlikely to be performed owing to the very large sample size that would be required, clinician preferences, and logistical and financial requirements for its conduct. In the meantime, we have over 30 years of experience and retrospective data¹⁸⁻²¹ supporting the efficacy of the combination as well as animal models documenting the superiority of the combination^{22,23} vs a complete lack of evidence that macrolide monotherapy is effective in foals with severe clinical pneumonia. Until it is documented that a macrolide alone is as effective as the combination with rifampin, the combination of a macrolide (erythromycin, azithromycin, or clarithromycin) with rifampin remains the recommended treatment for foals with clinical disease resulting from pneumonia.²⁴

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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.

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Antimicrobial Therapy in Neonatal Foals

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1. Introduction

Bacterial sepsis is the leading cause of morbidity and mortality in neonatal foals.¹ Many of the diseases involving the neonatal foal are the sequelae of bacterial infection. These diseases include pneumonia, peritonitis, meningitis, osteomyelitis, enterocolitis, septic arthritis, and omphalophlebitis. A high proportion (30% to 40%) of foals less than 2 weeks of age with noninfectious primary disorders such as neonatal encephalopathy, dysmaturity, or colic are also bacteremic.¹ Therefore, sick equine neonates have a high likelihood of bacterial sepsis and antimicrobial therapy is often indicated. The neonatal period represents a time of rapid growth and development. Changes in body composition and proportions, liver mass, metabolic activity, and renal function collectively affect the pharmacokinetic behavior of many antimicrobial agents. This text summarizes the age-related differences in the bioavailability and disposition of antimicrobial drugs and reviews the principles of antimicrobial therapy in equine neonates.

2. Absorption and Disposition of Antimicrobial Agents in Equine Neonates

Many beta-lactam antimicrobial agents that are poorly absorbed and cause digestive disturbances in adult horses can be administered orally to neonatal and young (up to approximately 4 months of age)

foals for the treatment of systemic bacterial infections caused by susceptible microorganisms. For example, oral bioavailability of amoxicillin is 30% to 50% in 6- to 7-day-old foals compared with 5% to 15% in adult horses.² Similarly, the oral bioavailability of cefadroxil (5% oral suspension) decreases progressively from 99% in 2-week-old foals to 68% at 1 month, 35% at 2 months, 20% at 3 months, and 15% at 5 months of age.³ This progressive decrease in oral bioavailability with increasing age does not occur for all beta-lactam antimicrobial agents. For example, the relative oral bioavailability of cefpodoxime proxetil is similar between 7- to 14-day-old foals, 3- to 4-month-old foals, and adult horses.⁴ The effect of age on oral bioavailability has not been studied as extensively for other classes of antimicrobial agents.

Given that disposition refers to the simultaneous effects of distribution and elimination, it is necessary to consider both components of the process when interpreting changes that occur during the neonatal period or in the presence of a disease state. In contrast with neonates of other domestic animal species, glomerular filtration rate and effective renal plasma flow remain relatively constant throughout the postnatal period in foals and are similar to or higher than that of adult horses.^{5,6} Less is known regarding hepatic maturation of the equine neonate in the perinatal period but evidence from the study

NOTES

Table 1. Common Antimicrobial Drug Dosage in Foals^{a,b}

Drug Preparation	Dose (mg/kg)	Dose Interval (h)	Route of Administration
Beta-lactams			
Benzyl penicillins			
Penicillin G (Na, K)	25,000 IU/kg	6	IV
Penicillin G (procaine)	25,000 IU/kg	12	IM
Aminobenzyl penicillins			
Ampicillin sodium	20	6	IV
Amoxicillin trihydrate	30	8	PO
Antipseudomonal penicillins			
Ticarcillin	50	6	IV
Ticarcillin-clavulanic acid	50	6	IV
First-generation cephalosporins			
Cefazolin	20	8	IV
Cefadroxil	20–40	8	PO
Second-generation cephalosporins			
Cefoxitin	20	6	IV or IM
Third-generation cephalosporins			
Cefotaxime	40	6	IV
Ceftiofur sodium	5	12	IV, IM, SC
Cefpodoxime	10	6–8	PO
Fourth-generation cephalosporins			
Cefepime	11	8	IV (foals)
Cefquinome	4.5	12	IV or IM
Carbapenems			
Imipenem ^c	15	6	IV
Aminoglycosides			
Amikacin	25	24	IV or IM
Gentamicin	6.6	24	IV or IM
	12	36	IV or IM (<2 weeks)
Tetracyclines			
Doxycycline	10	12	PO
Minocycline	4	12	PO
Macrolides			
Erythromycin (phosphate, stearate, ethylsuccinate, estolate)	25	6–8	PO
Erythromycin (lactobionate, gluceptate)	5	6	IV ^d
Azithromycin	10	24–48	PO
Clarithromycin	7.5	12	PO
Other			
Chloramphenicol (palmitate or base)	50	12	PO
Metronidazole	10–15	12	PO
Rifampin	5	12	PO
Trimethoprim-sulfonamide	30 (combined)	12	PO

^aAdapted from: Giguère S, Afonso T. Antimicrobial drug use in horses. In: Giguère S, Prescott JF, Dowling PM, eds. Antimicrobial therapy in veterinary medicine. 5th ed. Ames, IA: Wiley-Blackwell; 2013, 457–472.

^bAgents listed may be extra label and based on pharmacokinetic studies performed on small numbers of horses. As a result, efficacy and safety studies are often not available.

^cUse only when no other choice as indicated by culture and susceptibility testing and lack of clinical response.

^dAdminister as slow IV infusion.

of the pharmacokinetics of chloramphenicol (which is mainly eliminated by glucuronide conjugation) suggest that the microsomal-associated metabolic pathway develops far more rapidly in foals (within 1 week) than in neonates of other species.⁷ The pharmacokinetic parameters describing the disposition of gentamicin (4 mg/kg or 12 mg/kg, IV) indicate a profound and significant decrease in elimination half-life and apparent volume of distribution with increasing age with most changes occurring within the first 2 to 4 weeks of life.^{8,9} Given that the distribution of gentamicin is virtually restricted to the extracellular fluid (ECF), these findings are consistent with the fact that ECF volume is larger in

young foals than in adult horses. As a result of the larger volume of distribution, higher doses of aminoglycosides are recommended in foals less than 2 to 4 weeks of age. After 2 to 4 weeks of age, dosages recommended for adult horses are adequate (Table 1).

The direct effect of age on the pharmacokinetics of beta-lactam antimicrobial agents in the neonatal period has not been studied extensively. As expected, the volume of distribution of ticarcillin and cefquinome was significantly larger in neonatal (≤ 3 days) than in older foals (4 to 6 weeks).^{10,11} In contrast, half-life, systemic clearance, and volume of distribution of desferrioxime acetamide after in-

Table 2. Suggested Choices of Antimicrobial Agents for Selected Bacterial Infections of Foals^{a,b}

Disease	Suggested Antimicrobial	Alternative Antimicrobial
Neonatal infections ^c	Ampicillin-amikacin	Penicillin ^e -amikacin; Ampicillin-gentamicin; Penicillin ^e -gentamicin; ceftiofur
Bronchopneumonia (older foals)	Ceftiofur	Penicillin ^e ± gentamicin; trimethoprim-sulfonamide
Lung/abdominal abscesses	Macrolide ^d and rifampin	Doxycycline-rifampin; chloramphenicol-rifampin

^aAdapted from: Giguère S, Afonso T. Antimicrobial drug use in horses. In: Giguère S, Prescott JF, Dowling PM, eds. Microbial therapy in veterinary medicine. 5th ed. Ames, IA: Wiley-Blackwell; 2013, 457–472.

^bAgents listed may be extra label and based on pharmacokinetic studies performed on small numbers of horses. As a result, efficacy and safety studies are often not available.

^cBacteremia, umbilical infections, septic arthritis, osteomyelitis, and pneumonia (<3–4 weeks of age).

^dErythromycin, clarithromycin, or azithromycin.

^eCeftiofur could replace penicillin.

travenous administration of ceftiofur sodium to neonatal (<1 week of age) and 4–5 week-old foals are not significantly different.¹² Recommended dosages for selected antimicrobial agents commonly used in foals is presented in Table 2.

3. Antimicrobial Therapy for the Equine Neonate

Gram-negative bacteria account for 70% to 95% of the microorganisms isolated from cultures of blood samples in equine neonates, with *Escherichia coli* being by far the most common isolate.^{13–15} Other Enterobacteriaceae (*Klebsiella* spp., *Salmonella*

spp., and *Enterobacter* spp.) and nonenteric Gram-negative rods (*Pasteurella* spp. and *Actinobacillus* spp.) are also commonly isolated. Gram-positive cocci (β -hemolytic streptococci, *Enterococcus* spp., and *Staphylococcus* spp.) account for approximately 15% to 30% of isolates depending on the hospital.^{15,16} Treatment protocols for equine neonates must include antimicrobials with a high level of activity against enteric Gram-negative bacteria while providing adequate coverage against Gram-positive microorganisms. Bactericidal agents are preferred because neonatal foals have a naive im-

Table 3. Suggested Choices of Antimicrobial Agents for Common Bacterial Pathogens of Foals^{a,b}

Microorganism	Suggested Antimicrobial	Alternative Antimicrobial
Gram positive		
β -hemolytic streptococci ^c	Penicillin; ceftiofur	Ampicillin; macrolide; rifampin; chloramphenicol
<i>Staphylococcus</i> spp.	Cefazolin	TMS; rifampin; chloramphenicol
<i>Enterococcus</i> spp.	Ampicillin	Penicillin; chloramphenicol
<i>Rhodococcus equi</i>	Macrolide ^d and rifampin	Doxycycline-rifampin
<i>Nocardia</i> spp.	TMS	Amikacin
<i>Clostridium difficile</i>	Metronidazole	
Gram-positive anaerobes	Penicillin	Metronidazole; chloramphenicol
Gram negative		
<i>Pasteurella-Actinobacillus</i> spp	TMS; ceftiofur	Gentamicin
<i>Actinobacillus equuli</i>	Ceftiofur	Gentamicin; amikacin
<i>Bordetella bronchiseptica</i>	Gentamicin; amikacin	TMS; oxytetracycline
<i>Escherichia coli</i>	Amikacin	Gentamicin; enrofloxacin; ceftiofur; cefotaxime; cefepime
<i>Klebsiella</i> spp.	Amikacin	Gentamicin; enrofloxacin; cefotaxime; cefepime
<i>Enterobacter</i> spp.	Amikacin	Enrofloxacin; cefepime
<i>Pseudomonas</i> spp.	Amikacin	Ticarcillin; piperacillin; cefepime
<i>Salmonella</i> spp.	Amikacin	Enrofloxacin ^e ; cefepime
Gram-negative anaerobes	Metronidazole	Chloramphenicol; penicillin (not for <i>B. fragilis</i>)
Obligate intracellular pathogens		
<i>Lawsonia intracellularis</i>	Oxytetracycline; doxycycline	Macrolide ^d ± rifampin; chloramphenicol

Abbreviation: TMS, trimethoprim-sulfonamide.

^aAdapted from: Giguère S, Afonso T. Antimicrobial drug use in horses. In: Giguère S, Prescott JF, Dowling PM, eds. Microbial therapy in veterinary medicine. 5th ed. Ames, IA: Wiley-Blackwell; 2013, 457–472.

^bAgents listed may be extra label and based on pharmacokinetic studies performed on small numbers of horses. As a result, efficacy and safety studies are often not available.

^c*Streptococcus equi* subspecies *equi*, *S. equi* subspecies *zoepidemicus*, and *S. dysgalactiae* subspecies *equisimilis*.

^dErythromycin, clarithromycin, or azithromycin.

^eEnrofloxacin should not be used in young growing horses unless there are no other alternatives because of the risk of arthropathy. This adverse effect might occur with other fluoroquinolones.

immune system and their defense mechanisms against bacterial pathogens might be compromised. The combination of an aminoglycoside (preferably amikacin or gentamicin) with either penicillin, ampicillin, or ceftiofur is often initiated until culture results are available (Table 2). Such combination provides adequate coverage against approximately 90% of bacterial isolates recovered from blood cultures.^{16,17} Amikacin, although more expensive, is preferred to gentamicin because of its lower frequency of resistance among Enterobacteriaceae.^{13,17,18} Similarly, ampicillin is preferred to penicillin or ceftiofur because of its higher activity against enterococci.¹⁷ In situations when an aminoglycoside should not be used such as renal failure, adequate coverage is provided by a third- or fourth-generation cephalosporin such as cefotaxime or cefepime, respectively. Suggested choices of antimicrobial agents for common bacterial pathogens of foals are presented in Table 3.

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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How to Manipulate a Recumbent Horse (Entrapment, Clinical, or Technical Emergency Rescue Situations)

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1. Introduction

Recumbent horses are fractious, frustratingly difficult, and very dangerous to handle. Even dead horses represent a significant challenge to manipulate for staff safety due to their great weight and size.¹ Safe manipulation requires knowledge of anatomy and physiology to prevent injury when employing webbing or slings,² as well as proper personnel positioning (Table 1). The confined spaces that animals commonly are found (inside stalls, trailers, or entrapped in equipment or topography) require appropriate personal protective equipment such as helmets; and may require reaching, prying, and cutting tools (Fig. 1). Strategies and equipment to mitigate these situations in various recumbent positions (Table 2) are available but underutilized by responders; the effectiveness of proper response systems is further emphasized by appropriate procedures, equipment, training, and emergency drills.

Slides, drags, vertical lifts, and assists are basic to technical large animal emergency rescue—a specialty form of heavy rescue in the Fire and Rescue Services that is intimately tied to the veterinary practitioner's expertise and advice. Some poorer

methods that well-intentioned “rescuers” have used in the past reflect our predatory human instincts to solve the problem—but have caused iatrogenic injury in the equine victim (traumatic amputations, lacerations, asphyxiation, corneal damage, myopathy, neurologic injury, etc.³). Ironically, horses do not instinctively understand how to help themselves, or have the capacity to understand that responders are there to help.

The use of the methods presented here represent viable options for the successful extrication and transport of horses⁴ trapped during a disaster or emergency, or dead. Use of these equipment and procedures requires planning, coordination of resources, and personnel placement. For these reasons there is a need to coordinate the effort better to keep the victim, the practitioner, and their staff out of harm's way. Many animals, when manipulated out of the entrapment or enabled to roll to sternal, will rise and stand on their own; thus, facilitating self rescue is the best use of manipulations methods.

The purpose of this article is to suggest methods for response to horses that are recumbent due to being geriatric, debilitated, injured, or in daily

NOTES

Table 1. General Rules for Manipulation

1. Do not attach anything to the head, neck, or legs to pull on (only for guidance as in a halter). If you must use the legs (dorsally recumbent) then use webbing and padding to protect the delicate structures of the legs, but be very cautious of being inside the kill zone while attaching anything to legs or feet—Best Practice—approach from the dorsal side of the animal.
2. Use webbing with looped ends (instead of ropes) for any type of manipulation. The greater surface area and flat surface of the webbing will minimize injury to the skin and underlying structures. Or use padding to protect soft tissue structures.
3. Best Practice—use the pectoral and pelvic girdles as the attachment point for any manipulations. The muscle and bone structures here will protect the delicate soft structures (nerve, blood vessels, tendons, and ligaments) beneath.
4. Do not use the tail as an attachment point for any mechanical manipulations—only careful manual movement of the recumbent horse by no more than two people. It can be broken, injured, or traumatically amputated by application of excessive force.
5. Use a blindfold while horses are recumbent, to protect the downside eye and relax the animal. Ensure it is easily removable—a blindfold should be fastened so that it will fall off if the person handling the animal loses control of the animal. Panicked horses that get up and run loose with the blindfold still on will run in a straight line in fear until hitting a solid object or falls. The danger to people and the horse is palpable.
6. Whenever possible—allow the animal to self rescue—leave the legs free and the head and neck should have free movement so that the animal can balance and use their legs to assist themselves to get up and move out of the entrapment. A halter and lead rope are not intended for pulling the animal out—they are for guidance only.
7. Sedation and/or anaesthesia should be carefully evaluated by the practitioner based on the animal’s medical status, time in situ, and potential for injury to a person or itself. Helmets should be worn when working with recumbent animals, especially by the animal handler.
8. Protection of the downside eye is assumed in all of the methods described herein—horses use their head and neck as a lever to rise and when struggling may cause serious injury to an unprotected eye.
9. Always treat even dead animals with respectful and professional methods—you never know who is watching or taking a video. Social media is ever present.



Fig. 1. Preparing a recumbent horse in a confined space of a stall for transportation on a Rescue Glide to definitive veterinary care. Attendants are approaching from the dorsal side of the animal, which is sedated, blindfolded, and hobbled for physical and chemical restraint. Photo by Washington State Animal Response Team with permission.

clinical situations or as part of a technical rescue response scenario, while presenting simple techniques for manipulation of recumbent horses, and will place emphasis on the use of simple tools, webbing, equipment, and proper positioning of personnel to achieve safer and more effective results when moving recumbent (live or dead) horses in various situations commonly encountered in the practitioners’ daily work.

2. Materials and Methods

- Two pieces of 5-m-long, 10-cm-wide webbing or 2.5-cm-thick cotton rope (ponies and standard size horses).
- Two pieces of 10-m-long, 10-cm-wide webbing or 2.5-cm-thick cotton rope (draft horses).
- Cane or Boat Hook or Painters Pole for extension of the arm and guidance of webbing.
- Two pieces of 2-m-long, 10-cm-wide webbing with looped ends; one chest strap 1 m long; two prussick hitches 20 cm long, and overhead spreader bar for attachment to tractor/backhoe or chain hoist—or Hast Becker Sling System.

Rolling a Cast Horse

Horses commonly get “cast” in various positions in stalls (up against the wall), in depressions or ditches (in pastures and paddocks), and trapped where they cannot right themselves (fences or other obstacles) (Fig. 2). Since this often occurs to a horse that is not otherwise injured or sick, the animal is “fully charged” and capable of injuring a person easily. Geriatric or debilitated animals may need medical attention immediately. There are conditions where

Table 2. Recumbency Definitions

<u>Anterior:</u>	Occurs most often in animals involved in transportation incidents where the trailer goes nose down into a ditch, waterway, hole, or embankment and horses are not able to rise, where their heads are well below the rest of their bodies. Often the neck will be found at strange angles which impacts breathing, and the sheer weight of the abdominal contents pushes down on the lungs. A very rarely survivable scenario unless attended efficiently.
<u>Posterior:</u>	Common in animals that fall into holes, ditches, or other obstacles where the rump is well below the rest of their body.
<u>Dorsal:</u>	Befalls horses that fall or are thrust into a tight space and end up on their backs with their hooves pointed upward—this might be a water tank, feed bunk, ditch, horse trailer wreck, hole, or creek.
<u>Lateral:</u>	Most common position for a “downed” animal due to various scenarios from geriatric inability to get up, to injured, to debilitated to technical rescue scenarios. The sheer weight of the animal contributes over time to compartment/crush syndromes, myopathies, neuropathies and requires that the animal be attended quickly—within 4 hours of being down for the best opportunity at recovery.
<u>Sternal:</u>	The animal is laying on its ventral surface with legs either trapped in a downward position or folded and resting upon them. This is a preferred position for completing technical rescue scenarios at hand off to the veterinarian, and is considered the “recovery position” for downed equines.

the attending practitioner may not wish to roll the animal out of this position for medical reasons—in those cases one of the variations of the Forward Assist, Sideways Slide, or Backwards Drag should be selected.

There are three efficient configurations of correcting this cast entrapment position—SIMPLE ONE LEG, SIMPLE TWO LEG, and WEB ASSIST ROLL. In each case, pieces of 5-m-long, 10-cm-wide webbing or 2.5-cm-thick cotton rope may be used to roll the animal over the dorsum (use the longer webbing: 10 m for draft horses).

This procedure assumes that if the animals’ leg(s) or head are entrapped that they are going to be corrected first, before attempting to solve the cast condition. It also assumes that before the animal is rolled in a confined space (trailer, stall, ditch) that people performing the procedure have a pre-

defined escape route—as the animal comes over, it will often frantically attempt to stand. Affixing a halter with leadrope on the animal before rolling it and assigning one person as the animal handler will ensure better control of the horse when it gets up.

SIMPLE ONE LEG (Fig. 3)—This method allows a limited number of people to be successful at rolling the horse out of the cast position, or can be used in confined spaces where there is minimal room for an escape route by people. Because the pelvis of the horse is fixed, attaching rope or webbing to the downside hind leg at the pastern, then rolling the animal over the dorsum at a 45° angle from over the shoulder will ensure that the rest of the horse easily rolls when pulled. The rope or webbing should be placed on the pastern from a safer position at the dorsum—using a cane or long



Fig. 2. Examples of cast horses: Left, Horse cast in the corner of a pasture with legs under a barbed wire fence and with a hay bale behind. Right, horse cast in stall. Left photo by Laura Stack; right photo by Mattie Marohl with permission.



Fig. 3. Preparing for a Cast Horse Roll using a simple one webbing looped around the pastern of a mannequin for demonstration. The animal handler helps maintain the animal down until prepared to roll the horse, the webbing is placed at a 45° angle over the shoulder in preparation for pulling. Photo by permission.

pole to position it—which limits the chance of injury to the rescuer.

SIMPLE TWO LEG (Fig. 4)—When more people are available to assist with rolling the animal, or where the rescuers have more room for an escape route, this method is useful. Attaching rope or webbing to the downside legs (front and rear) from a safe position at the dorsum—using a cane or long boat hook or painter’s pole to position it around the pasterns, then pulling both pieces of the webbing away from the animal toward the dorsal aspect so that it rolls over the dorsum will easily free the animal. (If there are sufficient personnel to assist, three or four legs may be used.) This is similar to the



Fig. 4. Cast Horse Roll with two ropes attached to the downside legs in a crossed variation to give control. The 3rd leg is also bearing a rope since there are so many people available to assist with rolling the horse off of the L.A.R.G.E. Rescue Glide. Photo by Little Fork Fire Rescue with permission.



Fig. 5. A 1-in. cotton rope is used for tying off the hind leg for castration or other field surgical procedures and can be used in a girth hitch around the upper hind leg. A similar use can be applied to rolling a cast equine by attaching the rope to the downside rear leg. Photo by Dr Jennifer Proctor with permission.

girth hitch used by many practitioners to tie off a hind leg and prevent kicking during field surgical procedures (Fig. 5).

WEB ASSIST ROLL—This method may be useful in entrapment situations (especially slick mud) where it is easier to manipulate webbing under the downside legs, then pull the legs up and over to roll the entire animal onto better footing where it can stand. Use one piece of 10-m webbing under all four legs slightly above the hocks and carpus, and against the ground surface. Then the front portion of the strap is fed over the neck, while the back portion is fed over the buttocks of the horse. Working together, at least two persons pull from the dorsal area in a straight line and pull the animal over on its body axis.

FORWARD ASSIST—allows the legs to be free so that the horse can use their muscular effort to move forward, usually to solid ground. There are THREE configurations of this method: **SIMPLE/BASIC**, **CINCH/LARKSFOOT**, and **WIDENER/SWISS SEAT**. In each case, the webbing that runs in front of the animal should be kept out of the way of the animal’s



Fig. 6. Using a 10-m rope to remove a dead horse from a stall using a Forward Assist in the Simple configuration from a stall. The legs will be manipulated by use of tools or for a dead animal may be tied up to the body with rope or hay string to package the animal into a smaller size. Photo by Michelle Melaragno with permission.

hooves to minimize entanglement during the extrication. The permission assumes that rescuers have assigned an animal handler, who has attached an emergency rope halter or typical halter to the animal for guidance and control. It is crucial that no one pulls on the animals' head during the rescue, or else the animal will fight the assistance effort using opposition reflex. Once the animal begins to move forward it will often use its muscular power to move forward so egress routes should be cleared before asking the animal to move forward.

SIMPLE/BASIC FORWARD ASSIST (Fig. 6)—This configuration of the forward assist is the simplest to attach and remove, and the easiest to learn to use; however, it is also most subject to slipping and is not appropriate for vertical lift from posterior recumbency (out of manholes, etc., where only the forequarters and head are within reach.) A 10-m piece of webbing is laid over the animal's withers at the halfway point, then each end of the webbing is wrapped under the chest at the sternum and pulled anteriorly between the legs, then attached with a carabiner to a long rope for manual pulling.

CINCH/LARKSFOOT FORWARD ASSIST—This configuration of the forward assist literally cinches down around the animal's chest, minimizing the



Fig. 7. Simple configuration of the Forward Assist applied to a horse stuck in the mud, pulling it forward onto a Rescue Glide and demonstrating that it increases the surface area on the pectoral girdle of the animal. Photo by Hampshire Fire Rescue with permission.

chance of slippage. It is commonly used to tie an animal off in its current position (on top of a bridge or trestle for example) so that it cannot fall further into trouble. It is also recommended for vertical lifts from posterior recumbency (when a simple vertical lift with simple web slings is not possible, or when the equipment is not available.) One 10-m piece of webbing with loops at each end is wrapped around the animals' chest at the withers, then one end of the webbing is fed through the loop at the other end, fed anteriorly between the front legs, then attached with a carabiner to a long rope for manual pulling (Fig. 7).

For horses trapped in posterior recumbency (wells, manholes, etc.) the loop of webbing coming from between the front legs may be attached to an overhead lifting point to perform a vertical lift. We are aware of five occasions of live rescues using this method that were very effective. However, we prefer that the rescuer should use the Widener/Swiss Seat method described below because it doubles the surface area and ensures the horse's pectoral girdle is locked in and cannot fall out.

Note: A variation of this method has been used to lift cattle, elk, moose, and other bovids by using the 10-m piece of webbing with loops at each end, wrapped around the animal's chest at the withers and one end of the webbing fed through the loop at the top of the withers, then attached with a carabiner to an overhead crane for a vertical lift. The authors are not aware of any successful live rescues of horses using this method, but it represents a consideration in situations where there may not be any other option as an attachment point.

WIDENER/SWISS SEAT FORWARD ASSIST—This configuration of the forward assist cinches around the animal's entire forequarters and pectoral girdle, effectively doubling the surface area of the webbing on the animal's skin, therefore reducing the chance of injury from pressure used to pull the animal out of its entrapment. It also cinches down onto the chest, minimizing slippage. Highly recommended for posterior recumbency vertical lifts, this configuration is slightly more difficult to envelope around the animal, and does take more time to remove. However, it does not come off the animal if properly emplaced (Fig. 8).

One 10-m piece of webbing is held at the animal's chest below the thoracic inlet at the halfway point, then each end of the webbing is wrapped over the withers, around each side of the animal, down then under the chest at the sternum, then pulled anteriorly between the front legs; lastly, it is fed up through the existing webbing at the thoracic inlet; then both looped ends attached with a carabiner to a long rope for manual pulling.

SIDEWAYS SLIDE—this drag method is useful for minimizing the animal's instinct to struggle by adding pressure to the chest and abdomen while moving the animal up or to the side (trench, surface ice, ditch, flat ground, mud, etc.). There are two configurations of this method: **SIMPLE/BASIC** and **HAMPSHIRE SLIP**. Both require two pieces of 5-m-long, 10-cm-wide webbing (10-m length for draft horses). In both cases it is preferred that the head be controlled by the animal handler to reduce possible injury to the eye or facial paralysis. The weight of the animals' body is used to the advantage of the rescuers to keep it recumbent, and increases the surface area of the animal on the unstable ground surface (mud, etc.) while being moved to safe ground.

SIMPLE/BASIC (Fig. 9)—This configuration can be used to pull the animal sideways along the ground or on the surface of mud, or upward in a modified vertical lift from surface ice, ditch/trench or pool; or to roll and maneuver the animal into different positions on the ground (example: for placement onto a Rescue Glide). Two pieces of 3-m webbing are separately flossed under the animal into position (front position) around the abdomen directly behind the front legs, and (back position) around the abdomen directly in front of the back legs.

HAMPSHIRE SLIP (Fig. 10)—This configuration can be used to pull the animal sideways without



Fig. 8. Horse in simulated posterior recumbency for training.—webbing has been placed in the Widener/Swiss Seat configuration around the chest and pectoral girdle to double the surface area and provide better support to the vertical lift. Note: the head **MUST BE SUPPORTED** with an overhead attachment point or it will fall to the side and injure the animal. Photo by Battalion Chief Darrell Mitchell with permission.

causing it to roll or struggle out of position. This method has been used in serious mud entrapment scenarios to move a floundering horse over 200 m to safe solid ground. Two pieces of 3-m webbing are separately flossed under the animal into position (front position) around the abdomen directly behind the front legs, then the top portion of the strap is fed between the front legs, under the neck of the animal, and then back to the rescuers at the dorsal aspect of the animal; and (back position) around the abdomen directly in front of the back legs then fed between the back legs, under the tail, and back to the rescuers at the dorsal aspect of the animal.

BACKWARD DRAG (Fig. 11)—for removing an animal that is recumbent in a trailer or other entrapment where the only access is to the rear end/posterior of the animal (horse trailer, culvert, etc.) There is only one configuration of this method—a 10-m piece of webbing is encircled around the animal's pelvis with the center of the webbing at the dorsum above the spine at the loin. The pieces of webbing with loops on the end are fed toward the



Fig. 9. The sideways slide or drag is used to move animals on flat ground onto a sked. Here the sedated live animal is being pulled onto the L.A.R.G.E. Rescue Glide sked for attachment and packaging. Right, the mannequin is going to be pulled out of the ditch with a sideways drag using the green Rescue Glide for edge protection. Photos by permission.

abdomen, then are pushed between the back legs to a carabiner, which can be attached to a manual pulling system. This can often be easily effected by the use of extension poles or canes to move the legs without harming a rescuer. It is preferred that the head be controlled by the animal handler to reduce possible injury to the eye or facial paralysis.

VERTICAL LIFT is the last option because it usually involves heavy equipment and greater coordination and expense. When considering situations that require this method, ensure there is an alternate plan if the animal cannot stand on its own after lifting (Anderson Sling^a for long-term support, recumbent transport, or euthanasia).

Sedation is almost always required, and close coordination between the operator of the equipment and the animal handler. Vertical lifting has been well

covered in the veterinary literature for a large variety of simple to complicated slinging equipment^{a,b,c} and methods^{5,6} of horses, but one that is most commonly used by emergency responders and veterinarians in technical rescue scenarios is the Simple Vertical Lift Web Sling (Figs. 12 and 13; a commercial version available is the Becker Sling^d). Use of 2-m webbing directly behind the front legs supported with a chest strap across at the thoracic inlet to keep it in place, and another 2 m directly in front of the hind legs ensures the animal cannot escape. These webbings are connected to the spreader bar overhead with the prussick attachments, then the spreader bar is connected to the tractor/backhoe or chain hoist for lifting.

Benefits of Simple Vertical Lift Web Slings include equipment that is simple to employ, cheap to acquire, and the practical use of the Simple Vertical Lift systems has been shown in numerous situations. The technique makes the animal feel trapped and usually causes the horse to sulk or hang quietly during the lifting procedure due to the physical sedative effect, minimizing risk to itself and others.

A concern with implementing the Vertical Lift Sling is that personnel must be trained in its use to maximize safety when working around a trapped or recumbent, frightened animal to prevent being kicked or crushed. Initial sedation or light anesthesia of the animal is essential to allow the animal to be placed in the sling and to prevent it from struggling and injuring itself or the rescuers.

Lastly, vertical lift systems visually appear to place significant pressure on the abdominal area of the animal; however, abdominal, thoracic, and pulmonary perfusions have not been observed to be significantly impaired in rescued animals lifted in this manner for 2–12 min (>20-min lifts in training scenarios with demonstration animals over 200 training evolutions). Pregnant mares have been successfully lifted using this technique. Contact pressure is minimized when using wider straps for the lift because they increase the surface area of the contact points on the animal. When used in con-



Fig. 10. The Hampshire Slip is used to move an animal sideways without any chance of rolling. Additionally, when the animal stands up it allows the webbing to fall away freely. Webbing is placed under the pectoral and pelvic girdles, and through the legs. Working together, the two teams can pull and rotate the animal around obstacles. Photo by Tori Miller with permission.



Fig. 11. The backward drag is placed carefully around the loin of the pelvic girdle and between the legs to remove a horse backward from a trailer or tight spot. It may be flossed under the animal easily by lifting the back leg with a cane or boat hook. Right, it is easy to see that the webbing goes around the hip and through the back legs. Photos courtesy of Dr. Keith Stafford.

junction with appropriate lifting equipment Simple Vertical Lift Slings can provide a suitable means of short-term vertical lift of large animals.

RESCUE GLIDE SYSTEMS—Horses are notoriously difficult to move or transport when sternally or laterally recumbent. Their tendency to thrash in an attempt to stand can lead to further injury. There is little information in the literature providing viable solutions to this problem. Attempts by early practitioners to use low-wheeled tables, tarps, or simple plywood for this purpose were impractical or unprofessional in the field, at shows, in the clinic, and on racetracks.⁷

The L.A.R.G.E. Rescue Glide^e, Resquip Glide Mat System^f, CDA Products Rescue Glide^g, and

LARRCO Rescue Glide^h all provide practical means of moving a recumbent, nonambulatory horse. They are skeds that have been modified from the human version by increasing the length to 2 m or 2.5 m and by using a recycled polypropylene polymer plastic that does not crack or break under heavy use. Horses with serious injuries, displaying severe debilitation, or neurological symptoms can be easily relocated from a stall, removed from public view at an event/race/show, or even drawn along a wilderness trail to a horse



Fig. 12. Using a Becker Sling to lift a horse from a snow bank in January 2016. Here the fireman is first removing the chest strap in preparation for removal of the sling system from the overhead by pulling the orange webbing. The horse is wearing a head protector as well. Photo by Little Fork Fire Rescue, Virginia, with permission.



Fig. 13. Here students practice a vertical lift using the Becker Simple Web Sling and a crane. The mannequin is simulated to be sedated for this procedure to minimize struggling and possible injury to itself and handlers. The most dangerous times are at lift off and set down of the animal—when a live animal can get leverage and launch itself forward. Photo by permission.



Fig. 14. Down horse in a barn being sedated by a veterinarian before attachment to the Rescue Glide for transport to veterinary care in an equine ambulance. Working as a team to keep people in safe positions is the goal of large-animal rescue. Photo courtesy of Washington State Animal Response Team with permission.

ambulance for transport to definitive veterinary care (Fig. 14). These skeds have specialty access points, ratchet or webbing tie-down anchor straps, and metal attachment points for loading into an equine ambulance. A horse must usually be sedated during transport on these skeds to prevent further injury to itself or personnel. Use of Rescue Glide systems in both medical emergencies and technical rescues of trapped animals has been extremely successful for transport of horses with severe tendon lacerations, neurologic injuries or diseases, broken pelvises and extremities, or shock, to veterinary facilities.

3. Results

Collecting the actual number of recumbence events is impossible because it is such a common part of clinical practice, and prevents documentation of the success rate of using these methods. A literature search revealed a small pool of information about methods of moving horses that are recumbent, and an inconsequential amount of research into physiologic responses to these methods. Collection of anecdotal information on recumbent horses by the permission has revealed that numerous incidents occur; however, the reporting subject often does not have access to or receive the details that are most important to disaster scientists, technical rescue researchers, or veterinary epidemiologists. Manipulation methods training is not currently a part of the student curriculum of veterinary schools or veterinary technician programs, but could be extremely helpful to reduce injuries to employees and students assisting with horses in these situations, particularly to reduce work-related exposure to injuries. (These techniques work equally well on bovine, caprine, porcine, llamoid, and large exotics with minor modifications for behavior and anatomy.)

Much knowledge of how horses may be manipulated, and suggestions for better response procedures, come from a combination of knowledgeable veterinarians, horsewomen/men, actual accounts and photos/videos, and reports from professional emergency responders (fire/rescue, mounted police, animal control and sheriff's officers) that have responded to these incidents. For example, when pressure is applied on the chest and abdomen of a horse, it causes a physiological response that minimizes effort to struggle, resulting in a lessened ability of the animal to get up, especially if the head is managed well by the animal handler. This physical sedative effect has been utilized by farriers, veterinarians, and horsemen throughout history to cause horses to become quiescent for various procedures.

During the last 25 years much of the research and development of these procedures and methods has been documented by colleagues in large-animal and technical emergency rescue, not within the veterinary community. The authors' experiences providing student training in Technical Large Animal Emergency Rescue with practitioners, veterinary technicians, fire/rescue professionals, animal control, and law enforcement officers have demonstrated that many people are assumed to know—but actually do not know—how to help a recumbent horse in an emergency situation without putting themselves or the animal at risk. Fallacies related to recumbent animal response and poor understanding of correct methodologies in the general equine industry have grown out of the lack of scientific rigor available.

4. Discussion

Recumbent horses are very dangerous to manipulate. Injuries sustained by practitioners, their staff and clients (well-intentioned rescuers) on scene can have debilitating long-term effects on health, safety, and wellness of people. Slides, drags, vertical lifts, and assists are basic to technical large-animal emergency rescue—a specialty form of heavy rescue in the Fire and Rescue Services that is intimately tied to the veterinary practitioner's expertise and advice. Past use of methods such as pulling on the head, tail, or feet without relieving pressure points reflect our predatory human instincts to solve the problem—but have caused iatrogenic injury in the equine victim (traumatic amputations, lacerations, asphyxiation, corneal damage, myopathy, neurologic injury, etc.). When employing webbing or slings, extensions of the arm should be used, and before pulling proper personnel positioning should be considered to get the correct angle to effect rescue.

Many animals, when manipulated out of the entrapment or enabled to roll to sternal will rise and stand on their own; thus, facilitating self rescue is the best use of manipulations methods (Fig. 15). It prevents the practitioner from having to use more complicated slings or methods to effect extrication or rescue. Horses in emergency or clinical recumbence scenarios may have special medical concerns



Fig. 15. A horse cast in a ditch is assisted to self rescue by a trained team of fire department personnel by use of a piece of looped end webbing to assist this geriatric horse to rise more easily. In the left photo, the horse is pulled slightly out of the ditch, in the right photo they provide support to get her to sternal position and rise. Photos courtesy of Katherine Davis with permission.

such as severe injuries, stress, hyper- or hypothermia, dehydration, shock, and exhaustion. Coordination between the veterinarian and the response team is important to increase the efficiency of treatment on scene, facilitate the extrication and allow veterinary medical attention to be administered. The increased chance of shock when combining sedation with rescues is because the veterinarian may not be notified or physically able to arrive to treat the animal until several hours after the incident occurs.

Some animals in recumbency will need to be aggressively treated or euthanized based on the extent of their internal or external injuries—this is where the crucial involvement and advice of the attending veterinarian is mandatory. The use of sedation should be carefully evaluated when recumbence scenarios occur in wet or muddy environments, because the sedated horse could drown or cause physiologic thermal maintenance issues.

Large animals when recumbent represent a challenge to extricate from the numerous and common entrapments that they occur in. However, procedures used to safely and simply remove the animal from the situation require use of simple webbing, extension/reach tools for emplacement of webbing or slings, helmet for the handler and operational personnel, a halter for guidance and control by the animal handler, and coordination of personnel to pull or manipulate the animal. By successfully manipulating the body of the horse, the responders can encourage the animal to self rescue where possible, and minimize iatrogenic injury to the animal victim. The suggested methods provide a more professional, safe, and efficient response to horses that are recumbent due to being geriatric, debilitated, injured, or in daily clinical situations or as part of a technical rescue response scenario. With emphasis on the use of simple tools, appropriate protective equipment for personnel (i.e., helmets), looped-end webbing, equipment, and proper positioning of personnel, the practitioner and their staff can achieve safer and more effective results when moving recumbent (live or dead) horses in various situations commonly encountered in the practitioner's daily work.

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.

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^aAnderson Sling, CDA Products, Porter Valley, CA 95469.

^bLarge Animal Lift, CDA Products, Porter Valley, CA 95469.

^cLiftex Sling, Liftex, Inc., 443 Ivyland Road, Warminster, PA 18974.

^dBecker Vertical Lift Sling System, Hast, Inc., Floyd, VA 24091.

^eL.A.R.G.E. Rescue Glide (modified), Ben McCracken, B & M Plastics, Greenville, SC 29607.

^fGlide Mat System, Resquip, Ltd., Leighton, Welshpool, Powys SY21 8HH, United Kingdom.

^gRescue Glide, CDA Products, Porter Valley, CA 95469.

^hLARRCO Products, Large Animal Rescue Resource Corp., 926 N. Liberty St., Winston-Salem NC 27101.

How to Diagnose Cardiac Arrhythmias in the Field

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1. Introduction

Identification of a cardiac arrhythmia in the horse can be a confusing and sometimes startling finding. Certain cardiac arrhythmias, such as second-degree atrioventricular block, might be recognizable based on auscultation alone. Many other rhythm irregularities, however, are impossible to decipher with only a stethoscope. In any scenario, an abnormal cardiac rhythm can trick even seasoned clinicians. Thorough physical examination and careful cardiac auscultation can aid a practitioner in determining cardiovascular stability and significance of a cardiac arrhythmia. However, electrocardiography is the most appropriate means to confirm or achieve a rhythm diagnosis and should be employed whenever a cardiac arrhythmia is appreciated.

Despite the obvious benefits of performing electrocardiography, rhythm diagnosis can be difficult to achieve in an ambulatory setting. Portable electrocardiography machines occupy valuable truck space, often require electricity, and are hampered by tangled wires. Because indications for electrocardiography do not occur daily and are frequently unforeseen, veterinarians in the field are often caught in scenarios in which access to this diagnostic tool would be helpful but would require an additional farm call and additional time that can be difficult to justify.

The introduction of the AliveCor Veterinary Heart Monitor^a, a handheld wireless portable electrocardiography device, has helped to circumvent some of the obstacles that hinder the equine ambulatory veterinarian's routine access to electrocardiography. This device can be used to capture a reliable electrocardiographic tracing that will, in many instances, allow for cardiac rhythm diagnosis to be performed in the field.

2. Materials and Methods

The AliveCor Veterinary Heart Monitor can be purchased online through specific distributors. At the time of publication, the AliveCor Web site only distributes its newer Kardia Mobile model. Unlike the Veterinary Heart Monitor, Kardia Mobile has not been validated for veterinary use. Before using the Veterinary Heart Monitor, it is necessary to download the device's corresponding application onto a smartphone (Fig. 1). Most platforms require creation of a username and password; this helps to maintain a catalog of a user's recorded electrocardiograms.

The heart monitors are effectively smartphone cases; they fit appropriately onto the phone model for which they are compatible. If a standard smartphone case is already in place, it is not mandatory to remove that case and replace it with the heart mon-

NOTES

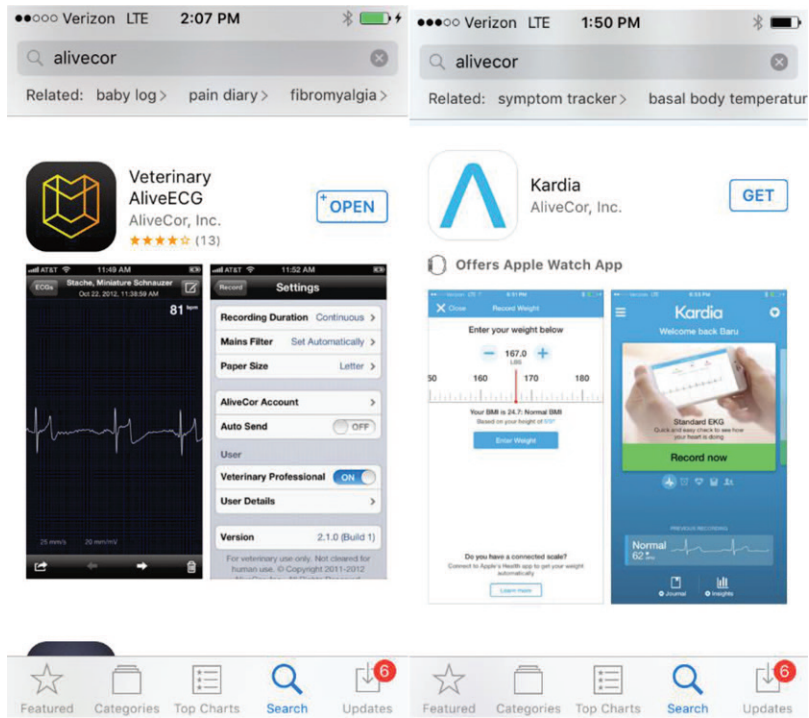


Fig. 1. Screenshots from iPhone 5S^b App Store to purchase AliveCor apps.

itor case. Most heart monitors can transmit a signal to the smartphone as long as they are in physical contact, even across a standard smartphone case (Fig. 2).

After auscultating the horse's heart, open the application on the smartphone. With the Veterinary Heart Monitor in contact with the smartphone, apply the electrodes of the device to the horse's skin. Amplitude of the electrocardiogram can be adjusted manually; importantly the amplitude of the tracing is also directly related to the proximity of the monitor to the horse's heart. As such, the device is most

appropriately applied to the left cranioventral thorax near the fifth intercostal space. Once contact with the horse's skin is established, the smartphone application should begin recording the electrocardiogram (single lead). If a tracing does not register, apply 70% isopropyl alcohol to the skin and place the Veterinary Heart Monitor on the skin (Fig. 3).

Duration of the recording is preset (typically 30 to 60 seconds) within the application and can be adjusted on the application's settings menu. At the conclusion of the recording period, the entire tracing can be reviewed in the application (Fig. 4). The



Fig. 2. AliveCor Veterinary Heart Monitor box and Veterinary Heart Monitor positioned for use in contact with iPhone 5S.

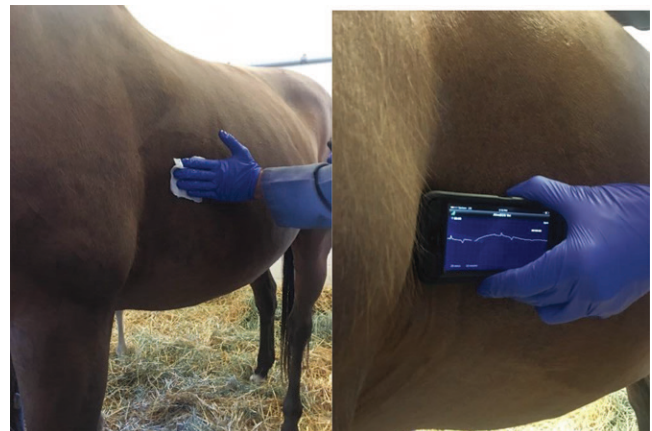


Fig. 3. Application of isopropyl alcohol and veterinary Heart Monitor to left cranioventral thorax.

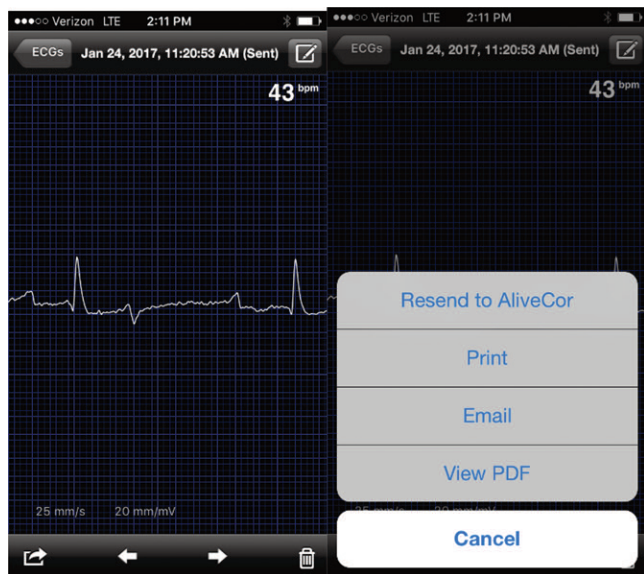


Fig. 4. Screenshots from iPhone 5S AliveCor App following recording of electrocardiogram.

electrocardiogram can also be immediately exported and/or emailed as a PDF file (Fig. 4).

In the author's opinion, the recorded electrocardiogram is best reviewed in PDF format. Once a clear tracing has been obtained it is ready to be analyzed. The first step in a systematic approach to electrocardiogram (ECG) interpretation is to measure the heart rate. The AliveCor application is capable of calculating the heart rate; this should be compared with findings from cardiac auscultation. Each dot on the electrocardiogram marks 1 mm. Each small box is 5 mm across; each large box is 25 mm across. If the paper speed of the electrocardiogram is 25 mm/s, each large box represents 1 s (Fig. 5). The number of QRS complexes in six consecutive large boxes should be counted and multiplied by 10 to estimate a heart rate.

Once heart rate is verified, cardiac rhythm should be categorized as regular or irregular. To objectively determine this, the R-R interval should be identified (distance between the peaks of QRS complexes) (Fig. 6). Whenever possible, calipers should



Fig. 5. AliveCor electrocardiogram at 25 mm/s paper speed.

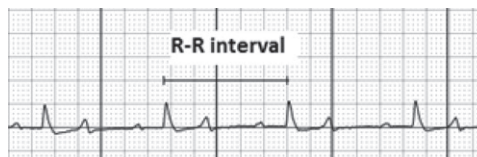


Fig. 6. AliveCor electrocardiogram in a horse in normal sinus rhythm. R-R interval is identified.

be used to measure each R-R interval as even subtle irregularities may be present but not apparent to the naked eye. If R-R interval is consistent, cardiac rhythm is considered regular. The most frequently identified regular cardiac rhythms in equine medicine include normal sinus rhythm, sinus tachycardia, supraventricular tachycardia, and isoform ventricular tachycardia. If R-R interval has any irregularities, cardiac rhythm is considered irregular. The most frequently identified irregular cardiac rhythms in equine medicine include sinus arrhythmia, atrial fibrillation, atrial premature complexes, ventricular premature complexes, and multiform ventricular tachycardia.

Next the electrocardiogram should be evaluated for the presence of P waves, QRS complexes, and T waves (Fig. 7). In normal sinus rhythm, every P wave is associated with a QRS complex and every QRS complex is associated with a P wave (Fig. 8). P waves (atrial depolarization) that are not associated with QRS complexes (ventricular depolarization) represent some form of atrioventricular block. QRS complexes that are not associated with P waves represent some form of junctional (arising from the atrioventricular node) or ventricular ectopy. Importantly, it is physiologically impossible for a T wave (ventricular repolarization) to be present without a preceding QRS complex; this concept can be helpful when interpreting complicated electrocardiograms.

The electrocardiogram must also be evaluated for P wave, QRS complex, and T wave morphology. The three primary components of wave morphology include polarity (positive or negative), amplitude (height), and duration (width). Among P waves, QRS complexes, and T waves, QRS complex morphology is arguably the most variable and clinically relevant in ECG interpretation in equine medicine.

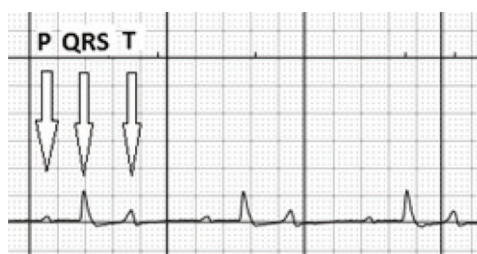


Fig. 7. AliveCor electrocardiogram in a horse in normal sinus rhythm. P wave, QRS complex, and T wave are identified.

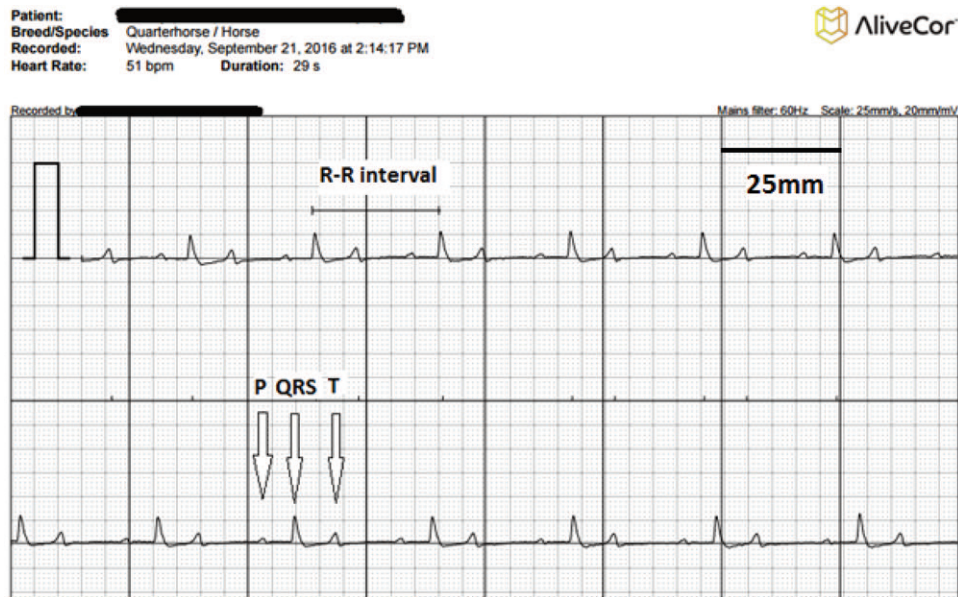


Fig. 8. PDF layout of an AliveCor electrocardiogram in a horse in normal sinus rhythm. P wave, QRS complex, and T wave are identified.

In normal sinus rhythm, QRS complexes should not only be paired with P waves but must be morphologically similar with respect to polarity, amplitude, and duration. Normal QRS complexes arise from the atrioventricular node and are conducted rapidly; as such these complexes are narrower than QRS complexes that arise from elsewhere in the ventricular myocardium. Ectopic ventricular beats are wider and are not preceded by P waves. A single ectopic ventricular beat is designated as a ventricular premature complex. Multiple (>3) consecutive ectopic ventricular beats are designated as ventricular tachycardia. Isoform ventricular tachycardia refers to multiple consecutive ventricular beats that all have identical QRS morphology. Multiform ventricular tachycardia refers to multiple consecutive ventricular beats that are of different QRS morphologies. The reader is directed to the reference below for a more extensive discussion of ECG interpretation.¹

3. Results

A recent study suggested that intra-observer agreement for rhythm assessment was very high when equine patients were evaluated using the AliveCor Veterinary Heart Monitor.² In this study, electro-

cardiography was performed on twenty horses using both the Veterinary Heart Monitor and a reference electrocardiography machine (base-apex lead). Instantaneous and average heart rates were within one beat in all horses when calculated. There was no disagreement with rhythm diagnosis between the two machines in any of the horses that were evaluated. As previously mentioned, AliveCor Kardia Mobile has not yet been validated in veterinary species. Although the Veterinary Heart Monitor seems to be a reliable assessor of cardiac rhythm, it is only capable of recording a single lead and might overlook subtle electrocardiographic disturbances that would be detected by machines that measure on six or 12 leads. Regardless, in practice the Veterinary Heart Monitor can aid in the diagnosis of many equine cardiac arrhythmias.

Of these arrhythmias, second-degree atrioventricular block is probably the most common in horses. It is associated with high vagal tone and should disappear with exercise and/or sympathetic stimulation. This rhythm is characterized by a consistent R-R interval. Occasionally a beat is “dropped,” meaning a P wave occurs with no successive QRS complex (Fig. 9). The distance between the preceding QRS complex and subsequent QRS complex

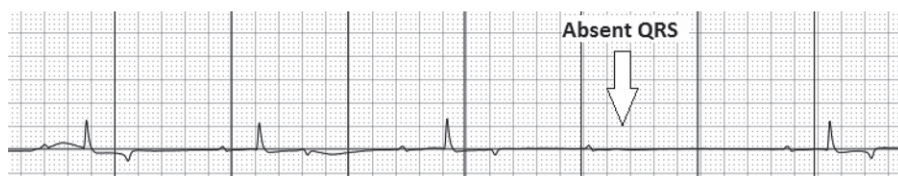


Fig. 9. AliveCor electrocardiogram in a horse with second-degree atrioventricular block.

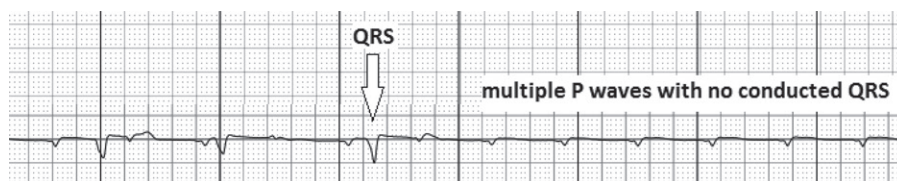


Fig. 10. AliveCor electrocardiogram in a horse with third-degree atrioventricular block.

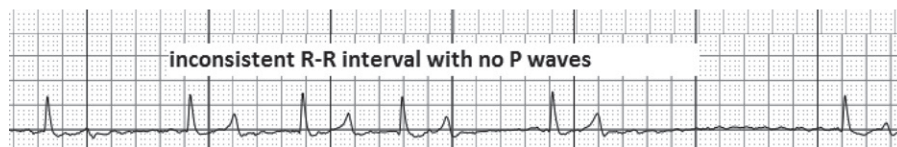


Fig. 11. AliveCor electrocardiogram in a horse with atrial fibrillation.



Fig. 12. AliveCor electrocardiogram in a horse with isoform ventricular tachycardia.

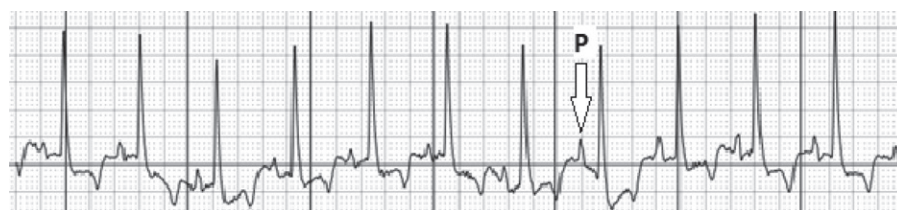


Fig. 13. AliveCor electrocardiogram in a horse with sinus tachycardia.

should be exactly twice as long as the other R-R intervals. Infrequently two consecutive dropped beats may occur normally; three or more consecutive dropped beats are not normal. Second-degree atrioventricular block is not pathologic in horses and does not warrant treatment.

Third-degree atrioventricular block is very uncommon in horses and might occur due to degenerative or inflammatory changes in the atrioventricular node. As such, multiple P waves will be observed without associated QRS complexes in the electrocardiogram (Fig. 10). QRS complexes that are observed may have been conducted through the atrioventricular node or may be “escape” beats. This arrhythmia may precipitate signs of collapse in affected horses and should prompt consultation with an internal medicine specialist or cardiologist.

Atrial fibrillation is a common cardiac arrhythmia in horses. It might be “lone” (occurring with no apparent underlying cause) or it might occur due to left atrial enlargement. Lone atrial fibrillation might be transient. Electrocardiographic findings for atrial fibrillation are characterized by an irreg-

ularly irregular rhythm; the R-R interval is never consistent (Fig. 11). Importantly, no P waves are present. P waves are replaced by “f” (fibrillation) waves in atrial fibrillation; in the author’s experience “f” waves are difficult to identify with the AliveCor Veterinary Heart Monitor. The absence of P waves and the presence of an irregularly irregular rhythm is consistent with a diagnosis of atrial fibrillation. Although not an emergency, atrial fibrillation that persists for longer than 24 to 48 hours should prompt consultation with an internal medicine specialist or cardiologist. Atrial fibrillation might represent structural heart disease, especially if it is associated with a cardiac murmur. Echocardiography is indicated in these cases. Atrial fibrillation can possibly be corrected by treatment with quinidine or by transvenous electrical cardioversion.

Sinus tachycardia and ventricular tachycardia are indistinguishable on cardiac auscultation. Electrocardiography is the primary means of differentiating these two rhythms and is a helpful diagnostic tool in horses with sustained tachycardia (Figs. 12 and 13). Isoform ventricular tachycardia is charac-

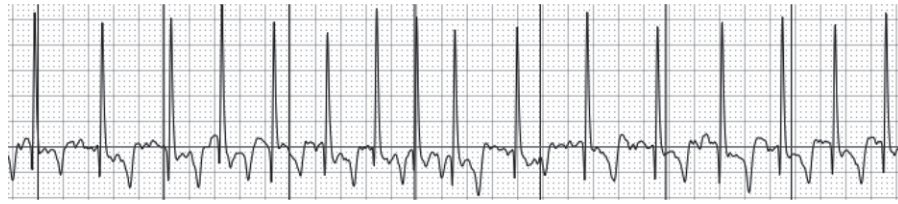


Fig. 14. AliveCor electrocardiogram in a foal with atrial fibrillation.

terized by a regular R-R interval. Importantly, P waves are absent. QRS complexes are wider but width and polarity should be consistent from beat to beat (Fig. 12). QRS complexes that vary in width and polarity from beat to beat more likely represent a diagnosis of multiform ventricular tachycardia. Rapid ventricular rhythms can precipitate congestive heart failure and/or cardiac arrest. Identification of a ventricular rhythm may warrant immediate treatment and, if needed, should prompt consultation with a consulting veterinarian or cardiologist.

Sinus tachycardia is also characterized by a regular R-R interval. The presence of P waves and narrow QRS complexes differentiates this rhythm from ventricular tachycardia (Fig. 13).

Lastly, changes in electrocardiographic morphology may be related to the Veterinary Heart Monitor itself. Polarity of all electrocardiographic waves is inverted by rotating the Veterinary Heart Monitor 180°. Width (duration) of electrocardiographic waves is not affected by position of the Veterinary Heart Monitor and will only be influenced by paper speed. Amplitude of all electrocardiographic waves increases as distance between the Veterinary Heart Monitor and the heart decreases. The QRS amplitude tends to be greater in foals and smaller horses, probably because of their smaller body size. In the electrocardiogram in Figure 14, note irregular R-R intervals that are consistent with a rhythm diagnosis of atrial fibrillation.

4. Discussion

The use of the AliveCor Veterinary Heart Monitor is a reliable means of establishing cardiac rhythm di-

agnosis in the field and is a helpful component to a complete cardiovascular examination. The Veterinary Heart Monitor's ability to create electrocardiographic tracings with a smartphone in an ambulatory setting facilitates immediate consultation with colleagues. Moreover, the apparatus is small, affordable, and can be purchased readily online. Although the device can only provide electrocardiographic tracings in a single-lead format, it offers substantially more information to the ambulatory veterinarian who is equipped with simply a stethoscope. The AliveCor Veterinary Heart Monitor provides a new dimension to cardiac evaluation in an ambulatory setting and can influence decisions to properly treat and/or refer affected patients.

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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How to Perform Abdominocentesis Using One-Handed Sterile Technique and Interpret Findings in the Field

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1. Introduction

From making a decision to euthanize a horse with a ruptured gastrointestinal tract to diagnosing uroperitoneum in a foal, abdominocentesis is a valuable component of the complete examination of the abdomen. Abdominocentesis can be used as a) part of the acute abdominal diagnostic work-up to assess for intestinal compromise and indications for surgery or euthanasia, b) as a diagnostic tool to differentiate peritonitis, neoplasia, and abdominal abscesses in horses with complaints such as chronic weight loss, and c) to diagnose hemoperitoneum or uroperitoneum in adult and neonatal patients.

Despite its obvious benefits to case management, equine practitioners may be reluctant to perform abdominocentesis in the field due to several limitations, including safety, inability to maintain a clean or aseptic environment, limited access to skilled helpers, and inability to interpret results in the field.

This paper describes the use of a one-handed sterile technique to perform abdominocentesis aseptically and easily in an ambulatory setting with simply a handler and a veterinarian present. This paper will also discuss how to form a "field diagnosis" based on gross characteristics of peritoneal fluid.

2. Materials and Methods

Considerations

Cleanliness

Ideally, abdominocentesis is performed in a dust-free and clean environment to decrease the possibility of contamination. The horse should be removed from the stall and the procedure performed in the cleanest area of the barn, with ample space for the veterinarian and handler to work safely. In many barns, this may be the wash stall or a grooming stall.

Safety

There are many advantages to performing technically challenging or invasive procedures in the hospital setting. The availability of skilled personnel who can handle the horse is one of those advantages. Abdominocentesis should only be performed in the field if the veterinarian feels that with the horse sedated and restrained that the handler is sufficiently capable of keeping both horse and veterinarian safe. Besides sedation, skin twitches, lip twitches, nose chains, and other distraction techniques can be helpful.

NOTES

Supplies

This paper will focus on abdominocentesis using a teat cannula. Advantages of the teat cannula include the blunt end, which may decrease the risk of inadvertent enterocentesis, and the larger bore, which allows greater chance of peritoneal fluid retrieval. However, the same procedure may be adapted for use of the bitch catheter, 18-gauge \times 1.5-inch needle, and 18-gauge \times 3.5-inch spinal needle.

The following supplies are gathered prior to beginning the procedure:

- Table (in the absence of a table, a tack trunk, straw bale, bag of shavings, grain bin, or garbage can with lid flipped over and blue towel placed on top may suffice)
- Chemical and physical restraint (the author typically uses 0.01 mg/kg detomidine IV and a nose twitch on the average-size horse)
- Clippers
- Materials for sterile prep (4 \times 4-inch gauze, 2% chlorhexidine or 1% betadine scrub, alcohol or sterile saline)
- Sterile gloves
- 2% lidocaine or 2% mepivacaine
- 3-cc syringe
- 25-gauge needle
- Sterile No. 15 blade
- Sterile metal teat cannula
- Sterile 4 \times 4-inch gauze
- 6-cc syringe
- Ethylenediaminetetraacetic acid (EDTA) tube
- Serum clot tube \pm heparin tube

Preparation

Once the materials have been gathered, EDTA should be shaken out of the EDTA tube. When less than 2 mL of peritoneal fluid is obtained, the EDTA can excessively dilute the sample by falsely decreasing cell counts, and can also falsely elevate total protein levels.^{1,2,3}

A site is selected for abdominocentesis at the most dependent portion of the abdomen for a greater likelihood of fluid accumulation, and to the right of midline to avoid the spleen and to avoid the surgical site if the horse undergoes a laparotomy.¹ This is typically 5 cm caudal to the xiphoid process and 2 cm to the right of the median raphe.⁴ This site is also easily recognizable by its location within a triangle formed by the insertion of the deep pectoral muscle, the ventral midline, and an imaginary line drawn from the most caudal aspect of the pectoral muscle to the midline (Figs. 1 and 2).

The following steps may be followed in preparation for the procedure:

1. Sedate the horse and apply a distraction technique if desired.
2. Clip the selected site for abdominocentesis and gather materials on the table (Fig. 3).



Fig. 1. The horse's abdomen is clipped to center around the site of abdominocentesis. In this image, the median raphe is being traced. The approach would be caudal to the xiphoid process, to the right of midline.

3. Prepare the site with sterile scrub. The author scrubs the area using 4 \times 4-inch gauze sponges soaked in 2% chlorhexidine or 1% betadine scrub, followed with 4 \times 4-inch gauze sponges soaked in sterile saline (if chlorhexidine is used) or alcohol (if betadine is used).
4. Before gloving, loosen the caps of the EDTA and serum clot tube so they can be easily removed using one hand.
5. Open sterile gloves on the previously prepared table to create a sterile field for working.
6. Open the 3-cc syringe, 6-cc syringe, sterile No. 15 blade, sterile teat cannula, and sterile 4 \times 4-inch gauze sponge onto the sterile field created by the packaging for the sterile gloves (Fig. 4).
7. Using open-gloving technique, don a sterile glove onto the dominant hand (Fig. 5).
8. Prepare the teat cannula by using the gloved hand to thread the teat cannula through the single 4 \times 4-inch gauze sponge (Fig. 6). The gauze will serve to soak up

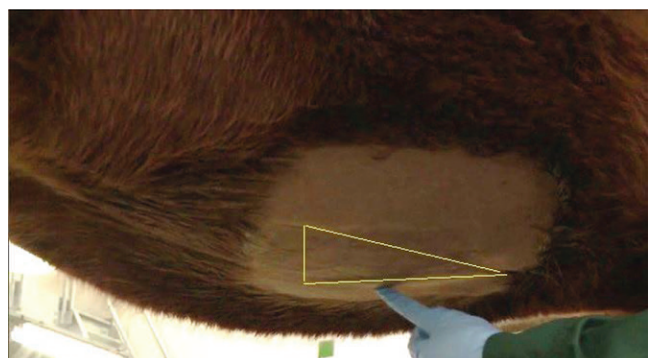


Fig. 2. The "triangle" formed by the deep pectoral muscle, midline, and imaginary line from caudal extent of the muscle to the median raphe are outlined. The procedure can be performed at any site within this triangle.



Fig. 3. Supplies for abdominocentesis on a makeshift table (grain storage bin) in the field setting.

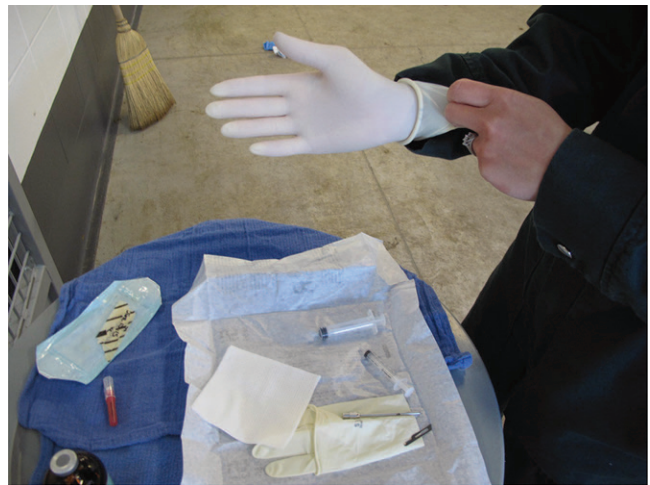


Fig. 5. A single sterile glove is applied on the dominant hand, using open-gloving technique.

blood and prevent contamination of the peritoneal fluid sample. There is a palpable and audible “pop” as the cannula pops through the gauze. This sensation is similar to the “pop” felt when the peritoneum is entered during abdominocentesis.

9. Holding the sterile 3-cc syringe using the sterile gloved hand, attach the 25-gauge needle using the ungloved hand.
10. Using the ungloved hand to hold the bottle of 2% lidocaine (or 2% mepivacaine) upside down, use the gloved hand and sterile 3-cc syringe and 25-gauge needle to withdraw 3 cc of lidocaine (Fig. 7).

Technique

11. Standing on the right side of the horse as closely as possible to the forelimbs for safety,

select a site for abdominocentesis within the area that has been aseptically prepped. Select a site that has no superficial blood vessels.

12. Let the handler know that the horse is about to receive an injection. Inject the lidocaine subcutaneously until a visible bleb forms (approximately 1 mL), then direct the needle perpendicularly through the site to block the muscle. Inject approximately 2 mL as the needle is withdrawn, to block the entire area that the teat cannula will advance through (Fig. 8).
13. Using the gloved hand, pick up the No. 15 blade and the sterile teat cannula with 4 × 4-inch gauze threaded through. Use the thumb and forefinger to hold the blade and



Fig. 4. Supplies laid out on a sterile field.



Fig. 6. Using the sterile gloved hand, the teat cannula is threaded through the sterile gauze. This serves to prevent blood contamination of the sample.



Fig. 7. Lidocaine is drawn up in a syringe by holding the bottle with the ungloved hand and drawing up the medication using the gloved hand.



Fig. 9. Using the ungloved hand, the lids are carefully removed from the EDTA and serum clot tubes.

the rest of the fingers to hold the teat cannula against the palm. Using the ungloved hand, pick up the EDTA and serum clot tubes. Hold them at an angle such that the caps can be removed by gently removing onto the table (Fig. 9).

14. Let the handler know that you are about to begin the procedure. Holding the No. 15 blade between the thumb and forefinger where the shank meets the blade, make a vertical stab incision through the lidocaine bleb, to the depth of the sharpened blade (Fig. 10). This will allow easier passage of the blunt teat cannula. The No. 15 blade can be disposed of.
15. Push the teat cannula vertically through the muscle of the belly wall using gentle upward pressure, taking care to hold it closer toward

the tip so that it cannot be accidentally advanced too quickly. There are two points of resistance felt as the abdomen is entered: one point as the teat cannula advances through the body wall, then a point of resistance before there is a “pop” sensation. This corresponds to the loss of resistance as a teat cannula enters the abdomen (Fig. 11).

16. Use the ungloved nondominant hand to catch peritoneal fluid as it drips out (Fig. 12). Collect samples in the EDTA tube (and heparin tube, if used) before the serum clot tube, given that the fluid can be analyzed from the EDTA tube while culture and sensitivity analyses are less often performed us-



Fig. 8. Using the gloved hand, a local block is performed.



Fig. 10. Holding the tubes in the ungloved left hand and holding the sterile teat cannula in the palm of the hand, a stab incision is made. The thumb and forefinger grasp the blade where the blade meets the shank to prevent an overly deep incision.

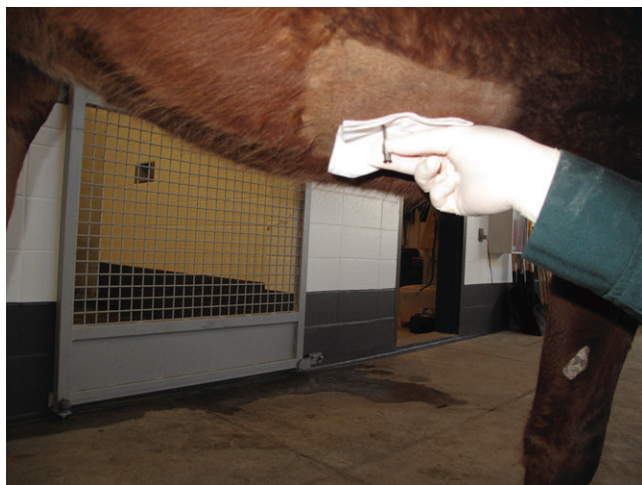


Fig. 11. The teat cannula is advanced through the peritoneal lining using the gloved hand.

ing the sample collected from the serum clot tube. When the procedure is complete, use a swift downward motion to remove the cannula.

Troubleshooting

The author has performed abdominocentesis using the one-handed sterile technique extensively with no adverse effects.

As depicted below (Fig. 13), there are a variety of strategies that may be employed when no fluid is obtained during abdominocentesis. First, evaluate the size and body condition of the horse. If the horse has thick retroperitoneal fat layers, a spinal needle or bitch catheter of longer length may need to be used. If the teat cannula seems to be the correct length for the size horse, the tip of the teat cannula may be pushed against the omentum inside the peritoneal cavity. Flicking or twirling the end of the



Fig. 12. The peritoneal fluid sample is collected using tubes held in the ungloved nondominant hand.

teat cannula or using the 6-cc sterile syringe to push in 5 cc of air can serve to “blow” the omentum off the tip. This step also confirms entrance through the peritoneum. If the cannula is outside of the peritoneal lining, the air will be expelled. If the cannula is inside the peritoneal cavity, the air will be retained. If these steps do not result in fluid recovery, a second teat cannula or 18-gauge \times 1.5-inch needle may be placed immediately caudal to the first teat cannula. This will help to overcome the negative pressure in the abdomen.² Pushing gently on the side of the horse may also allow more flow of peritoneal fluid.² If no fluid is obtained after these techniques are employed, abdominocentesis may be repeated at a different time after rehydration with IV fluids if the horse is dehydrated. Note that normal horses with normal amounts of peritoneal fluid may not yield a sample on abdominocentesis.³

Occasionally, splenic puncture may contaminate a peritoneal fluid sample. Gross characteristics can aid with a field diagnosis. For example, a splenic tap tends to yield a dark red opaque color and turbidity, small volume of blood, and ability to clot when settled out, as compared with peritoneal fluid and true hemorrhagic effusion.³ When a centrifuge and refractometer are available, splenocentesis may be differentiated from blood contamination and hemorrhage through centrifugation, the identification of platelets (as compared with erythrophagocytosis), and comparison of packed cell volume (PCV) as depicted below^{2,3} (Figs. 13 and 14):

- When PCV > peripheral PCV, the peritoneal fluid likely reflects a splenic tap
- When PCV = peripheral PCV, the peritoneal fluid likely reflects blood contamination
- When PCV < peripheral PCV, the peritoneal fluid likely reflects hemoperitoneum

As an invasive procedure, abdominocentesis may be associated with other adverse events. For example, contamination during the procedure may result in cellulitis of the abdominal wall. This may be treated using a course of broad-spectrum antibiotics. In addition, omental herniation may occur, especially in young foals. This may be treated by removing the omentum just as it exits the body wall. Enterocentesis can be treated using a 3- to 5-day course of antibiotics. This can be differentiated from a rupture through systemic clinical signs and the absence of neutrophils on cytology (Fig. 13).

3. Results

One of the limitations of performing abdominocentesis in the field is the lack of resources for laboratory analysis. However, the author has been able to gain diagnostic and prognostic information from gross characteristics of peritoneal fluid and laboratory parameters that may be measured in the field using portable equipment.

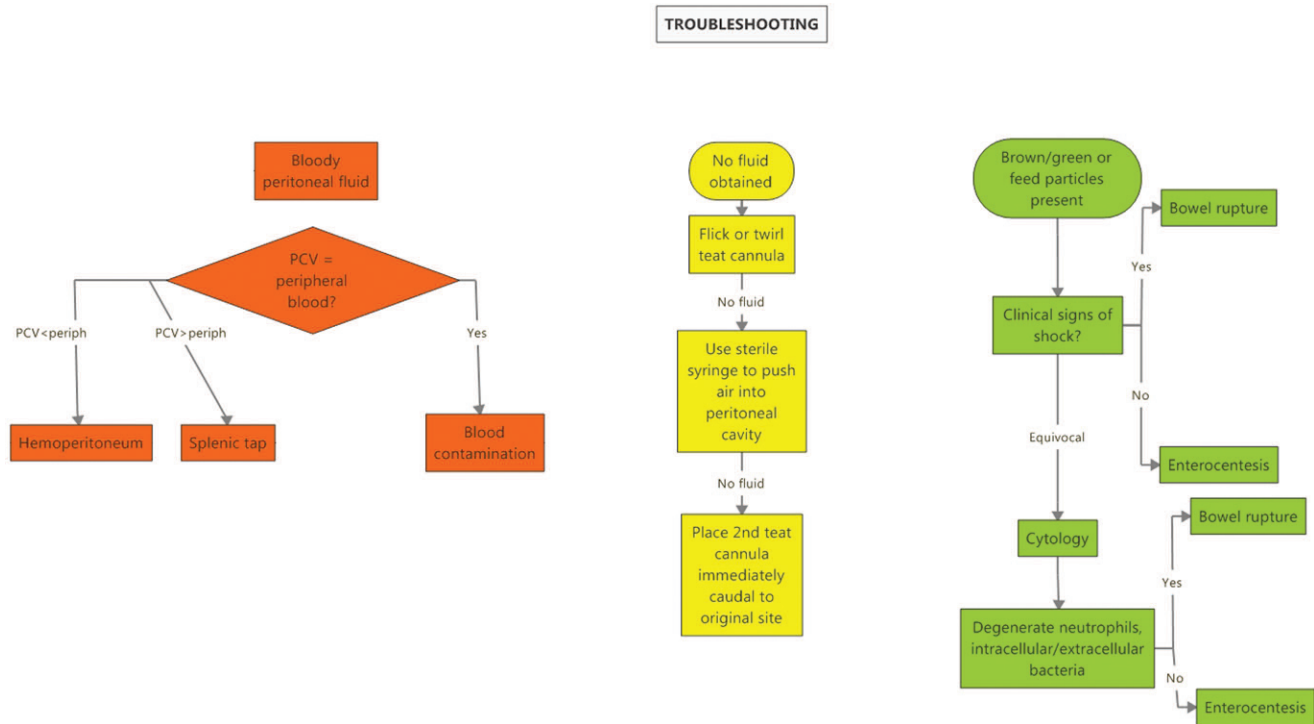


Fig. 13. Techniques used for troubleshooting abdominocentesis. Note that some of these techniques may require further laboratory analysis, beyond what is available in the field.

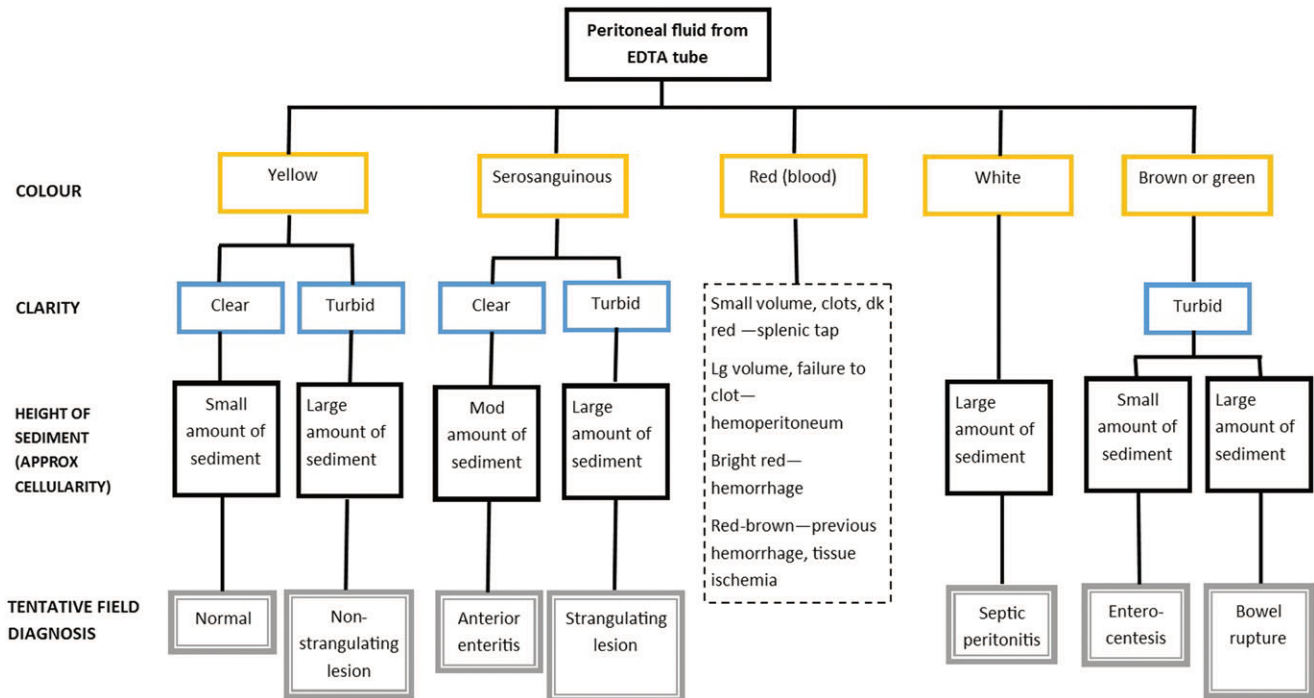


Fig. 14. Gross characteristics of peritoneal fluid leading to a field diagnosis.³

The first parameter that may be evaluated in the field is volume of peritoneal fluid collected. When greater than 100 mL of fluid is collected, this may suggest the presence of effusion or in-

creased abdominal pressure from intestinal distention.^{3,5}

Together with volume, the color and clarity of peritoneal fluid can lead to a field diagnosis (Fig. 15),

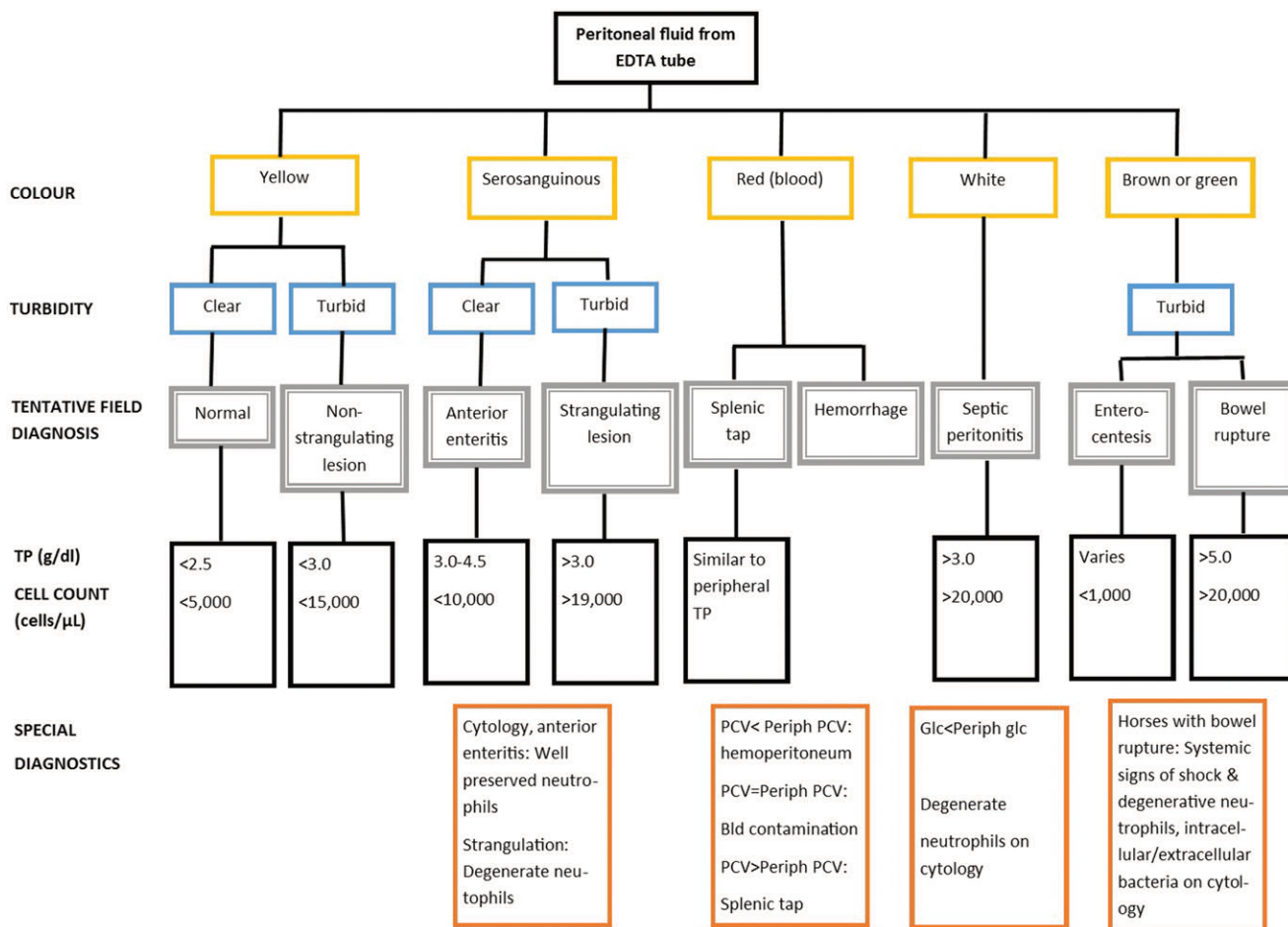


Fig. 15. Ancillary diagnostics performed in a reference laboratory can be used to further characterize peritoneal fluid after a presumptive diagnosis achieved in the field.^{3,4}

allowing an ambulatory practitioner to make diagnostic and prognostic decisions. During intestinal compromise, duration and severity are reflected in turbidity (increasing turbidity suggests increasing cellularity or protein levels) and color (reflecting the type of cells present).^{2,5} Normal peritoneal fluid is light yellow (color of straw) and clear. During the first 2 hours of compromise, total protein increases, causing an increase in the intensity of the yellow color. Red blood cells begin to leak in the first 4 hours, resulting in a serosanguinous color, and after 6 hours of compromise, white blood cells increase during intestinal necrosis.¹ Particulate matter in the fluid may represent fibrin from inflammation and plant material from enterocentesis or rupture. Peritoneal fluid color correlates with prognosis for survival, with the dark red color (color of port wine) suggesting tissue ischemia and necrosis and being associated with strangulating lesions and nonsurvival.^{3,6}

By allowing peritoneal fluid to sediment by gravity in the field, a rough estimate can be made of the cellularity of the fluid. The height of the sediment

is generally proportional to the cellularity, and different colors correlate with the ratio of red blood cells and nucleated cells.³

Further information to confirm a field diagnosis can be obtained using small portable equipment such as a refractometer, glucometer, or lactate meter. Normal peritoneal fluid has a total protein of less than 2.5 g/dL and protein increases with intestinal compromise.^{3,5} For example, horses with septic peritonitis yield total protein levels of greater than 3 g/dL.⁵ They also yield glucose levels lower than that of peripheral blood, often exhibiting glucose concentrations of less than 40 mg/dL.³ Peritoneal lactate should be less than 2 mmol/L and if greater than peripheral lactate, can indicate intestinal compromise and ischemia. Peritoneal lactate of >9.4 mmol/L has been correlated with no chance of survival.⁶ In cases of sepsis, a peritoneal sample in a serum clot tube can be saved for culture and sensitivity.

Some cases may be more complex due to ambiguous results, results that conflict with the clinical picture, compartmentalization of severe disease, or

values may be within reference range due to early detection of severe intestinal compromise.² In these cases, further information may be garnered through laboratory analysis, including nucleated cell count and cytology. The nucleated cell count of normal fluid is 5000 cells/ μL ³ and septic peritonitis may yield cell counts of upward of 20,000 cells/ μL .⁵ Furthermore, creatinine can be measured and when greater than twice systemic creatinine, can indicate uroperitoneum.⁷ Although cell count and cytology cannot typically be performed in the field, a reference is provided (Fig. 15) for further diagnostics that may occur if the samples can be submitted to a laboratory.

4. Discussion

Many equine ambulatory practitioners hesitate to perform abdominocentesis in the field due to inability to maintain aseptic technique, concerns about number of people present, and the perception that limited information can be gained from the peritoneal fluid in the field.

The author has performed numerous abdominocentesis procedures in the field with no reported instances of cellulitis, infection, or swelling. The author chooses locations within the barn that are the most dust free, such as a matted wash stall, and the use of the one-handed sterile technique eliminates the need for an assistant. Using this technique, the procedure can be performed with simply a handler present, while preserving aseptic technique.

The author has been able to use the physical characteristics of peritoneal fluid to guide treatment decisions in the field, without access to laboratory equipment. Decisions for surgical referral and euthanasia decisions have been made promptly based on peritoneal fluid volume, color, clarity, and sedimentation by gravity. In the author's experience, field diagnoses have correlated well with results from surgery and post-mortem examination.

However, cases are not always straightforward, and as a horse's clinical signs progress during a severe colic episode, the character of the peritoneal fluid may change as well. Field diagnostics are limited in the early detection of severe disease. In these cases, access to laboratory equipment to analyze protein levels, cell counts, and cytology can be most valuable. When clinical signs are more severe than field assessment of the character of peritoneal fluid, the author relies more heavily on the clinical

signs of the patient and when referral to a facility is available, this recommendation is made. Despite these limitations for specific cases, collection and interpretation of peritoneal fluid in the field is invaluable for the vast majority of horses who present with colic and chronic weight loss.

5. Conclusion

In summary, abdominocentesis can be performed safely, efficiently, and aseptically in the field using the one-handed sterile technique and the assistance of only a handler. Using gross visual characteristics and minimal portable equipment to evaluate the peritoneal fluid, a general equine ambulatory veterinarian can arrive at a field diagnosis and make informed decisions, from the surgical referral of a horse with compromised intestine to a euthanasia decision on a horse with a ruptured gastrointestinal tract.

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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How to Diagnose and Treat Equine Gastric Glandular Disease

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1. Introduction

Equine gastric ulcer syndrome (EGUS) has been recently divided into equine gastric glandular disease (EGGD) and equine gastric squamous disease (EGSD) based upon accumulating evidence that risk factors and pathophysiology for lesions of each location may differ.¹ Due to the potential differences in mechanisms of formation, there are differences in treatment and management recommendations for EGGD.

Prevalence and Risk Factors

Prevalence of EGGD is variable, depending upon breed and discipline of horse. Interpretation of prevalence is confounded by the fact that different studies report prevalence including any type or severity of glandular disease, and other studies report only grade 2 or greater. Prevalence of glandular disease range from 10% to 65%.²⁻⁸ Higher prevalence of EGGD are reported in Warmbloods and sporthorses, with EGGD grade ≥ 2 of 46% to 65%.^{4,6} A recent study suggested that Warmbloods are at increased likelihood for gastric glandular disease compared with other breeds.⁹ In that study, the only other variable associated with increased likelihood of EGGD was increasing number of caretakers.⁹ In sporthorses, signalment was not

associated with increased likelihood of glandular gastric disease.⁴ In Thoroughbred racehorses, factors identified as associated with increased likelihood of EGGD include sex, trainer, direct contact between horses, absence of grass turnout, being fed unprocessed grain, not being fed haylage, and decreasing days spent exercising at a high intensity, and swimming.¹⁰

Pathophysiology: Naturally Occurring Disease

There is limited information on the pathophysiology of gastric glandular disease. In squamous disease, increased exposure to hydrochloric acid has been proposed to contribute to lesion formation. However, given that the glandular mucosa is continuously exposed to hydrochloric acid, it is more likely that breakdown of normal mucosal barriers is primarily responsible for initiation of lesion formation rather than exposure to hydrochloric acid alone. Glandular mucosal defenses include blood flow and mucous secretion. In other species, prostaglandins have been demonstrated to be key to mucosal defense.

In humans, *Helicobacter pylori* is associated with gastritis and gastric ulcers. Several studies in

NOTES

Table 1. ECEIM Glandular Lesion Description¹

ECEIM Lesion Description	
Anatomic location	Cardia Fundus Antrum Pylorus
Distribution	Focal Multifocal Diffuse
Character	Flat and hemorrhagic Flat and fibrinosuppurative Raised and hemorrhagic Raised and fibrinosuppurative Depressed (\pm blood clot) Depressed and fibrinosuppurative

horses have investigated the role of *Helicobacter spp.* in formation of gastric ulcers and/or gastritis in horses. One study demonstrated that 90% of horses with gastric lesions had *Helicobacter*-like DNA, whereas 39% of horses without gastric lesions had *Helicobacter*-like DNA.¹¹ However, lesions of affected horses were not stratified by location (squamous versus glandular). Administration of *Helicobacter equorum* to a small number (n = 4) of healthy horses did not lead to gastric colonization.¹² *Helicobacter pylori* DNA was isolated from the glandular mucosa of 3/8 horses with grade 4 glandular disease, and in 0/5 horses with grade 1 to 2 EGGD and 0/9 horses with normal glandular mucosa.¹³ *H. equorum* was not identified in 10 horses, including five with grade 4 glandular disease.¹³ The role of *Helicobacter spp.* in gastric glandular disease remains unclear.

To date, there has been one study evaluating the histologic appearance of glandular lesions. This study demonstrated that most horses with glandular disease have histological evidence of gastritis.¹⁴

Pathophysiology: Nonsteroidal Anti-Inflammatory-Induced Lesions

Administration of nonsteroidal anti-inflammatory (NSAID) drugs can induce lesions of the stomach which are primarily, but not exclusively, glandular in location.¹⁵⁻¹⁹ Although gastric ulcers in other species are primarily associated with inhibition of prostaglandin synthesis, other mechanisms may contribute to gastric ulceration, including uncoupling of mitochondrial oxidative phosphorylation,²⁰ reduced hydrophobicity of the mucosal barrier,^{21,22} and topical cytotoxicity.²³ Furthermore, the one study performed to date in horses suggest that decreased glandular prostaglandin E (PGE) or prostaglandin I (PGI) concentrations are not associated with formation of glandular lesions following phenylbutazone administration.²⁴ However, administration of a PGE analogue prior to phenylbutazone administration did prevent the formation of glandu-

Table 2. Modified EGUS Scoring System¹⁰

Lesion Description	
Grade 0	Epithelium is intact, no evidence of hyperemia
Grade 1	Epithelium is intact but there is evidence of hyperemia
Grade 2	Small single or multifocal (<5) superficial lesions
Grade 3	Large single deep or multiple (>5) focal superficial lesions
Grade 4	Extensive lesions with areas of apparent deep ulceration

lar lesions, suggesting increased prostaglandin E is protective against lesion formation.¹⁸ The mechanism of NSAID-induced equine glandular gastric disease remains to be determined.

2. Materials and Methods

Diagnosis

Clinical signs are nonspecific for diagnosis of gastric disease, whether glandular or squamous. Diagnosis is confirmed via gastroscopy. There are currently two glandular disease scoring systems: a descriptive, which was proposed in the recent European College of Equine Internal Medicine (ECEIM) consensus statement,⁴ and a quantitative 0 to 4 scale,¹⁰ which was adapted from the EGUS Gastric Ulcer council scoring system²⁵ on squamous ulceration (Tables 1 and 2). As the relationship between disease pathophysiology or severity and either scoring system remains to be established, scoring using both systems may be prudent. Representative images of the different scoring systems are presented in Figs. 1, 2, 3, 4, and 5.



Fig. 1. Grade 0 glandular mucosa (normal).

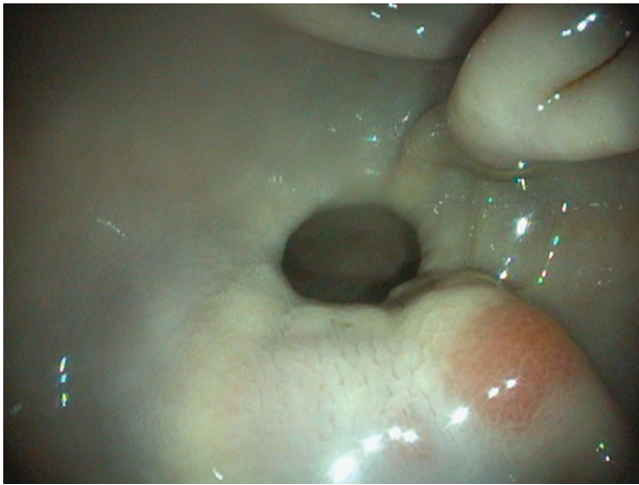


Fig. 2. Modified EGUS grade 1 glandular disease.

3. Results

Treatment of Naturally Occurring Disease

There have been several prospective studies evaluating treatment of equine gastric glandular disease. *Gastrogard*^a remains the treatment of choice for gastric ulcers of any type due to the large number of studies supporting its efficacy. A recent study suggests that several different commercially available oral formulations of omeprazole were not bioequivalent, although differences between formulations were relatively minor.²⁶ Although no large-scale studies have been performed to compare healing rates between *Gastrogard*^a and other commercially available products, one study using a formulation of enteric-coated granules suspended in a paste had healing rates that were similar to those previously reported for *Gastrogard*.^{a27} In contrast, compounded omeprazole has been shown to be less effective than *Gastrogard*,^a which may in part be due to the pH of the formulation.²⁸ Recommended dosing regimens may differ among available omeprazole products, and compounded formulations are typically less effective.

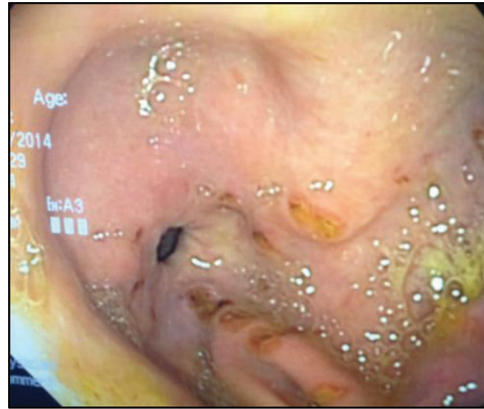


Fig. 4. Modified EGUS grade 3. ECEIM description, multifocal, depressed, and fibrinosuppurative.

Regardless of the product used, glandular disease seemed to be more difficult to treat than squamous disease. In one study, healing of EGSD grade ≥ 2 was observed in 86% of horses administered 1, 2, or 4 mg/kg omeprazole for ~28 days, whereas healing of EGGD grade ≥ 2 was only observed in 14% of horses.²⁷ Improvement was also better in horses with EGSD (96%) compared with EGGD (34%).²⁷ The reason for the difference in healing is unknown, but it may be that either acid suppression alone is insufficient for glandular lesion healing or that more profound acid suppression than what is achieved at standard dosing regimens is required for glandular lesions.

Recent data suggest that both type of diet and/or duration of fasting prior to omeprazole administration may impact both pharmacokinetics and pharmacodynamics of omeprazole.^{29,30} Importantly, feeding free-choice hay leads to decreased time of acid suppression (30% to 40% of time of pH<4) compared with feeding a combination grain and hay diet (80%). Therefore, fasting horses prior to administration of omeprazole may be warranted. Exact time of fasting necessary to promote enhanced acid suppression is not known, but it is currently recommended to fast overnight prior to *Gastrogard*^a

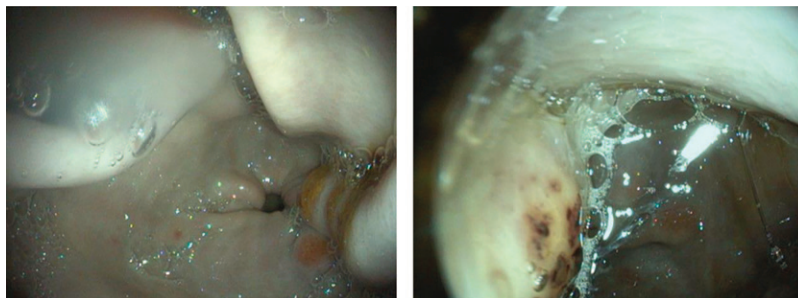


Fig. 3. Modified EGUS grade 2 disease. Left, ECEIM description, multifocal, flat, and suppurative. Right, ECEIM description, focal, flat, and hemorrhagic.



Fig. 5. Modified EGUS grade 4. ECEIM description, raised, and hemorrhagic.

administration and then for approximately 90 minutes afterward.^b If fasting is not possible, then increasing dose or increasing frequency may be warranted.

Other treatments that have been evaluated in healing of glandular lesions include sucralfate, misoprostol, and trimethoprim-sulphadimidine, and dietary supplements. Omeprazole plus sucralfate resulted in 65% healing rate.³¹ Another study suggested that misoprostol may be superior to omeprazole plus sucralfate in healing, but not improvement, of glandular disease.³² One study in a small number of horses suggested that combination trimethoprim-sulphadimidine with omeprazole did not result in superior healing compared with healing with omeprazole alone.³³ Therefore, routine use of antimicrobials in treatment of glandular disease is not presently recommended. A study in a small number of horses suggested that treatment with a polysaccharide may be beneficial.³⁴ However, this study was neither blinded nor placebo controlled, making interpretation of results challenging. Based upon the studies to date, the authors recommend using combination therapy of omeprazole with sucralfate, or omeprazole with misoprostol, as first-line therapies. Due to the poor healing rate observed with glandular compared with squamous disease, it is important to perform gastroscopy in horses with glandular disease at 4 to 6 weeks, prior to discontinuing treatment. Total duration of treatment would be expected to be at least 6 to 8 weeks. If no response is observed at repeat gastroscopy, adding in additional treatments (i.e., adding in misoprostol if initial therapy consisted of omeprazole and sucralfate) may be warranted. Unfortunately, there is no data on the pharmacokinetic or pharmacodynamic interactions between these drugs when used in combination therapy.

Table 3. Recommended Medications for Treatment of Equine Gastric Glandular Disease

Medication	Dose
Misoprostol	2 to 5 $\mu\text{g}/\text{kg}$ PO every 8–12 hours
Omeprazole	4 mg/kg PO every 24 hours (plain or buffered) 1 mg/kg PO every 24 hours (enteric coated)
Sucralfate	12 to 20 mg/kg PO every 6–12 hours

Treatment of NSAID-Induced Lesions

For NSAID-induced lesions, misoprostol (Table 3) is recommended, although there is limited data to support its use. There is one study that suggests it is effective for prevention of phenylbutazone-induced glandular lesions.¹⁸ The author (HEB) evaluated efficacy of misoprostol in healing of phenylbutazone-induced lesions in six horses. Following 2 weeks of treatment, (5 $\mu\text{g}/\text{kg}$ PO every 8 hours in molasses), 2/3 misoprostol-treated horses and 0/3 placebo (molasses only) horses had glandular lesion healing. In horses with NSAID-induced mucosal erosion or ulceration, omeprazole may be helpful in reducing acid exposure and additional damage. Following discontinuation of NSAIDs, it is anticipated that 2 to 4 weeks of treatment would result in resolution of NSAID-induced EGGD. The authors recommend repeating gastroscopy to evaluate lesions prior to stopping treatment.

4. Discussion

Glandular disease can be more difficult to treat than squamous disease, and may require ancillary therapies. Duration of treatment prior to resolution of EGGD is typically longer than that observed for EGSD. Type of feed and duration of fasting should be considered when determining treatment protocol.

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.

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Clinical Implications and Hospital Outcome of Immune-Mediated Myositis in Horses

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Immune-mediated myositis is a cause of rhabdomyolysis, stiffness, and muscle atrophy predominantly affecting Quarter Horses. Limited information is available with regard to outcome, prognostic indicators, and associations with concurrent diseases. Authors' addresses: Equine Sports Medicine & Surgery, 2991 Interstate 20 Frontage Road, Weatherford, TX 76087 (Hunyadi); Kindred Biosciences, Inc., 555 Old Bayshore Hwy #200, Burlingame, CA 94010 (Sundman); Departments of Population Health & Reproduction (Kass), Veterinary Medical Teaching Hospital (Williams), and Department of Medicine & Epidemiology (Aleman), University of California–Davis, Davis, CA 95616; e-mail: emily.sundman@kindredbio.com, lmh89@cornell.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

To report outcomes and associations between outcome and clinical and laboratory parameters, and presence of concurrent illness.

2. Materials and Methods

Medical records of 68 horses with histological diagnosis of immune-mediated myositis (IMM) were reviewed (1991–2014).

Data recovery included signalment, laboratory variables, therapy, and outcome. Logistic regression was used to quantify the association between potential prognostic factors and survival to discharge.

3. Results

Quarter Horses were younger (mean < 4 years; range, 3 months to 21 years) than other breeds

(mean < 10 years; range, 1 to 23 years). Pathogens causing concurrent or recent infection included *S. equi equi*, *S. equi zooepidemicus*, *C. pseudotuberculosis*, *Anaplasma phagocytophilum*, herpes virus-1, and influenza. The most common clinical signs consisted of rapidly progressive diffuse symmetrical muscle atrophy (80%), stiff gait (74%), and fever (44%). All horses that received medical therapy immediately upon admission survived to discharge (survival proportion, 87%).

Leucocytosis was a common finding (60%). Horses with concurrent fever and other illness had a poor prognosis for hospital discharge.

4. Discussion

Horses with IMM can have a favorable outcome. Horses with concurrent fever and another illness had decreased probability of survival to discharge.

Research Abstract—for more information, contact the corresponding author

NOTES

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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.

Seroprevalence and Risk Factors Associated with Equine Coronavirus in Healthy Horses in the United States

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This study showed that the seroprevalence to equine coronavirus (ECoV) was 9.4% in 5247 adult, healthy horses from 18 different states. Seropositivity was significantly associated with horses from the Midwest, draft horses, and specific uses including ranch/farm and breeding use. Authors' addresses: Department of Medicine and Epidemiology, School of Veterinary Medicine, University of California–Davis, Davis, CA 95616 (Pusterla, Mapes); and Department of Equine Sciences, Faculty of Veterinary Medicine, Utrecht University, 3584 CM, Utrecht, The Netherlands (Kooijman, Theelen); e-mail: npusterla@ucdavis.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Despite the sporadic occurrence of ECoV outbreaks in adult horses, the overall seroprevalence of this virus in horse populations has remained poorly investigated. Seroprevalence data are needed to better understand the epidemiology of ECoV, evaluate diagnostic modalities, and develop preventive measures. Therefore, it was the objective of this study to investigate the seroprevalence and selective risk factors to ECoV in 5247 healthy adult horses originating from 18 states using a recently established and validated ELISA.

2. Materials and Methods

Blood samples were available from 5247 healthy horses from 18 different states representing the four regional areas of the United States. The serum samples were tested for antibodies to ECoV

using an ELISA. Mixed-effects logistic regression models were created to determine prevalence odds ratios.

3. Results and Discussion

The overall seroprevalence of ECoV in horses was 9.4%. Horses from the Midwest displayed the highest seropositivity to ECoV in the region category. Draft horses showed the highest seropositivity in the breed category. Ranch/farm and breeding horses displayed the highest seropositivity in the use category. There was no significant difference in ECoV seroprevalence for the sex and age categories. Implications of these results are contemporary knowledge on the background infection rates and geographic distribution of ECoV in horses.

Research Abstract—for more information, contact the corresponding author

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The study was supported by the Center of Equine Health, School of Veterinary Medicine, University of California–Davis. Zoetis, Inc. supplied the equine sera used in this study. Zoetis, Inc. played no role in the analysis and interpretation of data.

Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.

Review: A Field Guide to Better Radiographs

Kurt Selberg, MS, DVM, MS, DACVR*;
Kathryn A. Seabaugh, MS, DVM, DACVS, DACVSMR; and
Myra F. Barrett, MS, DVM, DACVR

Patient preparation and positioning, adequate technique, and knowing how to correct malposition radiographs are skills in achieving diagnostic radiographic images. Taking a moment to assess unintentional obliquity, patient conformation and stance, and appropriately using distance and collimation can reduce retakes and reduce radiation exposure. Authors' address: Colorado State University, 300 West Drake Road, Fort Collins, CO 80524; e-mail: ktselberg@gmail.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Lameness is a frequent medical problem in horses. Aside from localizing techniques such as palpation and subsequent diagnostic blocking, radiographic investigation of the limbs, neck, and back is often the first choice in diagnostic testing. Digital radiography is widespread and arguably considered the standard of practice. The advantages of digital systems include the ability to manipulate images, apply post processing, centrally store, and quickly obtain and review images immediately after acquisition. Despite these advances in technology, the basics of radiographic exposure and patient positioning have not changed. When producing radiographic images using digital technologies, the veterinarian or technician must still correctly position and choose a technique appropriate for the body part being imaged. Faulty imaging due to poor positioning or inappropriate exposure can lead to under- or over-diagnosis of pathologic changes. The goal of diagnostic imaging is to reach an accurate diagnosis to target treatment specifically. Well-positioned ra-

diographic images acquired with the appropriate technique are a key component to reaching the correct diagnosis.

2. Principles of X-Rays

When a radiographic image is obtained, approximately 90% of the x-ray photons are absorbed by the tissue and 10% of the photons pass through the patient and reach the detector. Many of the absorbed photons generate scattered radiation (Compton scatter). These scattered photons travel in all directions creating noise and degrading image quality. The effect of scattered radiation can be minimized by collimating the x-ray beam to reduce the number of scattered photons (Fig. 1).

The inverse square law states that the intensity or quantity of photons reaching the x-ray detector is inversely proportional to the square of the distance from the source. In other words, the farther away you are from the patient the less intense the photons are that strike the plate. This is especially important for obtaining radiographic images in large body parts with portable generators. The typical film

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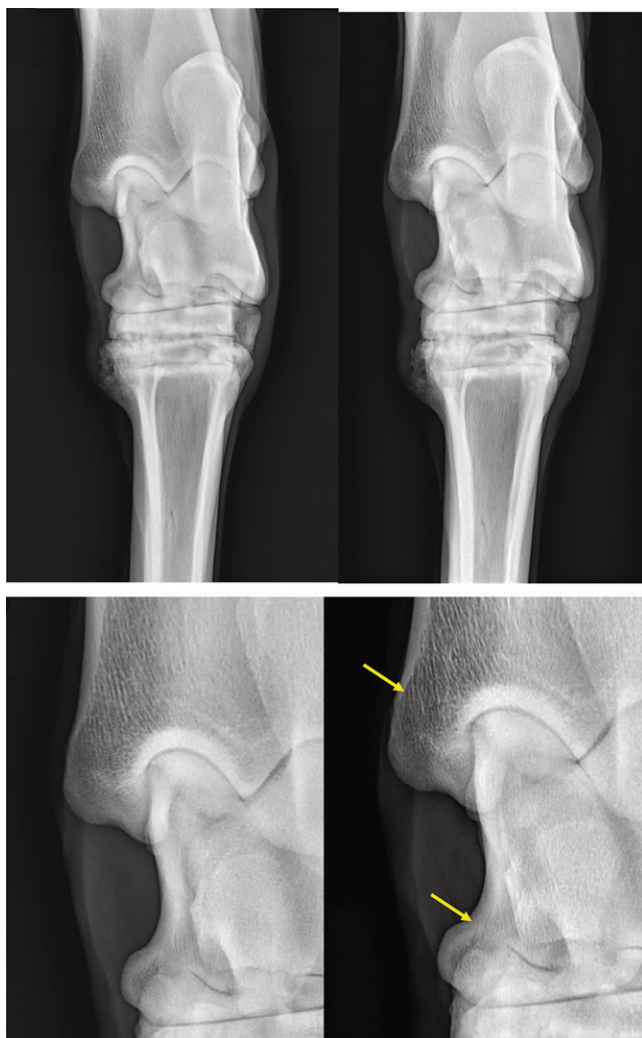


Fig. 1. DP tarsus images. The image on the left is obtained with the collimator left open. The image on the right is obtained with the collimator narrowed to the boundaries of the tarsus. There is moderate improvement of contrast and fine detail in the image obtained with the narrowed collimator. The bottom images represent the corresponding images magnified to better illustrate the improved detail and contrast due to the reduction in scatter. This is best seen in the medial malleolus and medial aspect of the talus (arrows).

focal distance (distance from the plate to the generator) is 60 cm. When imaging larger body parts such as the caudocranial stifle, neck, or back it is important to maintain this distance. We can also use the inverse square law to our advantage and stand closer to the image detector and patient to improve image quality when imaging larger body parts. By standing closer when obtaining radiographs of larger body parts, the increased quantity and intensity of photons reaching the plate will help to reduce the commonly obtained gray, grainy images (also known as quantum mottle; Fig. 2).

Despite the ability to use electronic markers, the lead marker is still the gold standard in displaying

laterality. The positioning of the plate can vary the placement of the electronic marker, making it unreliable for denoting laterality. Although a proper physical label (displaying limb and projection) is ideal, even a penny or paperclip taped to the plate to denote lateral is better than no marker at all.

A large amount of patient data can be displayed on the digital image. Although it is essential to include patient information in the radiographic study, the amount of text burned onto the subject matter of the image should be minimized. The overlaying patient demographics, if burned into the image, can superimpose on the included anatomy and mask pathologic change; this is especially true when collimating as the resultant image is small in relation to the text size. Thus, take care not to compromise the value of the radiograph by poor positioning of study labeling, particularly as this information is readily available in all Digital Imaging and Communications in Medicine (DICOM) viewers and is not necessary to include on the images.

3. Patient and X-Ray Positioning

The ideal conditions for obtaining most radiographs of equine joints is with the horse standing square except for non-weight-bearing views. Unfortunately, not all of our equine patients are willing to stand square. As such, the equine practitioner must accommodate the patient to make quality radiographs. Radiographic examination of the stifle, especially the caudocranial image is a good example of this principle. For example, the optimal angle for the caudocranial image is 10° from caudal proximal to cranial distal¹ with the horse standing square (the tuber calcaneus is in line with the tuber ischii). However, if the limb is slightly behind the vertical (camped out), or under the horse (camped under), the angle must be adjusted to accommodate the stance of the horse. If the horse is standing with the limb behind it, the angle (caudoproximal to craniodistal) will increase (be steeper) and vice versa for the horse that is stood under itself (Fig. 3). When evaluating the caudocranial stifle image for adequate positioning, the tibial plateau should superimpose itself from cranial to caudal and the tibial tuberosity should be distal (10 to 15 mm) to the tibial plateau (Fig. 4). If the tibial tuberosity is proximal to the tibial plateau, the angle is typically too steep. The x-ray generator should be centered approximately 8 to 10 cm proximal to the indentation created by the distal aspect of the thigh musculature as it transitions to the proximal crus area. Joint narrowing in the stifle may be masked or falsely created by inadequate positioning. The most common areas of pathologic change in the stifle are associated with the medial femoral condyle and the lateral trochlear ridge,^{2,3} the caudo45 lateral-craniomedial (Cd45L-CrM) oblique highlights these areas well. A well-positioned Cd45L-CrM oblique should project the medial femoral condyle caudal to

Table 1. Radiology Positioning Checklist

Positioning checklist	
Tarsus	
DP	Calcaneus should be projected over the lateral cortex of the tibia Distal joints should be lucent and equal width
LM	Trochlea should be superimposed Distal joints should be lucent and equal width
PLDM-0	The medial trochlear ridge should split the lateral trochlear ridge
Stifle	
CdCr	Tibial plateau should superimpose Tibial tuberosity should be 10 to 15 mm distal to tibial condyle
Cd45L-CrM-O	Medial femoral condyle should be separated from tibial eminence Medial femorotibial joint should be clearly visible
Foot	
Skyline	Joint between middle phalanx and navicular bone should be well seen
D60P	Distal aspect of navicular bone should be projected proximal to distal interphalangeal joint Distal border should be well delineated
Fetlock	
DP	Proximal sesamoid bone should be projected 10 to 15 mm proximal to fetlock joint
DLPM-O/DMPL-O	Proximal sesamoid bones should be projected 5 mm proximal to the palmar/plantar tuberosity The axial surface of the sesamoid projected dorsally (completely superimposed with the condyle) should be in line with the plantar/palmar margin of the sagittal ridge

the tibial eminence and show the joint clearly (Fig. 5). The superimposition of the medial femoral condyle with the tibial eminence can mask subtle concave defects. Just as with the caudocranial pro-

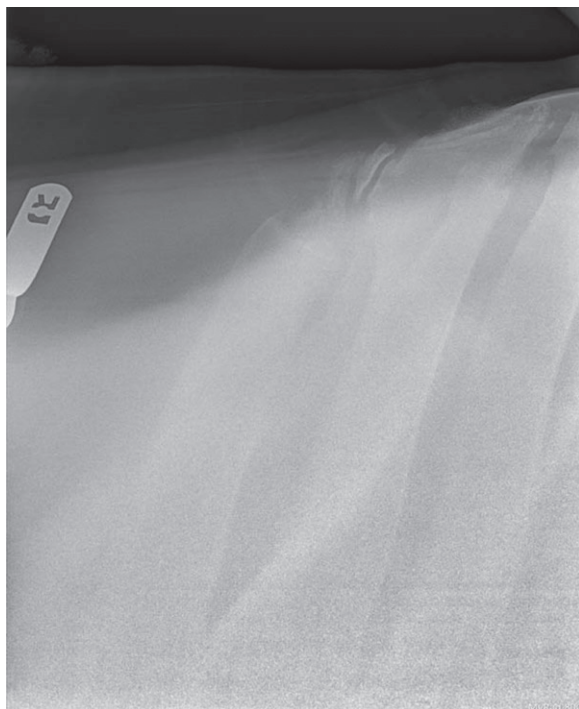


Fig. 2. Radiographic image of the cranial thoracic spinous processes. The structures in the lower right portion of the image is highlighting quantum mottle/under exposure which is characterized by a grainy appearance. Compared with the dorsal aspect of the spinous processes, there is good anatomic definition and contrast.

jection of the stifle, the angle of the x-ray generator should be 5–10° proximal to distal in a square standing horse. The most common mistakes are to be too steep of an angle or being too lateral. The Cd60L-CrM oblique seemingly highlights the lateral trochlear ridge. However, a well-positioned lateral projection has a similar sensitivity to the Cd60L-CrM oblique projection 77% vs 84%, respectively.⁴ Limb positioning also affects acquisition of the lateral radiographic projection. If the horse is standing base wide the x-ray generator will have to be angled distally; if base narrow, the generator angle will be slightly proximal. Judging placement of the x-ray generator in a cranial-to-caudal fashion is best done by lining up with the heel bulbs and tarsus. The most common mistake is being too far cranial.

Just as with the stifle, the x-ray generator angle on dorsoplantar radiographic projection of the tarsus must change depending on conformation and stance. A horse with a normal angle to the tarsus, standing square, will require a 5–10° proximal to distal angle, centered on the central tarsal bone to see the distal joints. If instead the horse has a post-legged conformation the x-ray generator angle should be relatively parallel with the ground. Similarly, if the limb is held behind the vertical, and has a normal tarsus angle, the x-ray generator will be parallel with the ground. It is also important to note that on the true dorsoplantar (DP) image the calcaneus can superimpose over the distal tibia and talus, masking lesions found there (Fig. 6). In most circumstances shifting the x-ray beam slightly laterally (Dorso 10°lateral-plantaromedial oblique) will eliminate calcaneal superimposition from the majority of the tibiotarsal joint and highlight the medial malleolus to evaluate for osteochondral disease.



Fig. 3. The left image illustrates a horse that is standing camped under. The red arrow illustrates the flat angle and proper center for the x-ray generator. The right image illustrates a horse that is slightly camped out. The yellow arrow illustrates a steeper angle (approximately 15°) of the x-ray generator.

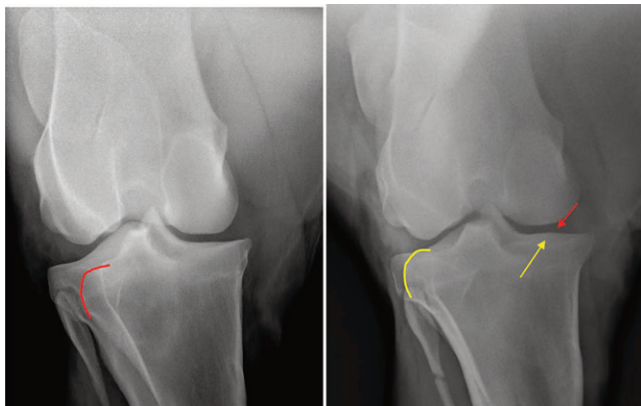


Fig. 4. Caudocranial images of the stifle. The left image is well positioned with a 10° angle. The curved red line is highlighting the tibial tuberosity. The tibial tuberosity is projected distal (10 to 15 mm) to the lateral tibial condyle. The cranial and caudal aspects of the medial tibial condyle superimpose. A comparison image (right image) of a caudocranial image that is obtained at too steep of an angle. Note that the tibial tuberosity (yellow line) is projected at the level of the lateral tibial condyle and the caudal (yellow arrow) and cranial (red arrow) aspects of the medial tibial condyle are separated.

Medial malleolus articular lesions may also be masked on conventional DP images by summation of the malleolus with the talus. The lateromedial projection should have the trochlea of the talus super-

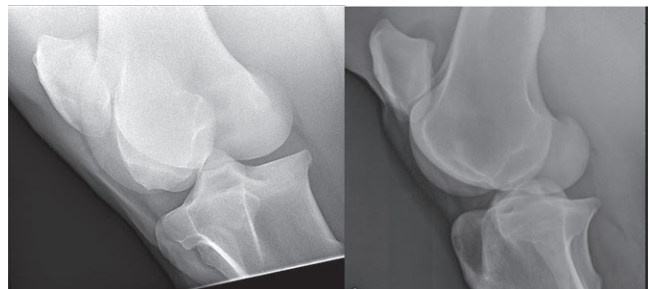


Fig. 5. Caudo45Lateral-craniomedial (Cd45L-CrM) oblique images. The left image is a well positioned Cd45L-CrM oblique image. The cranial aspect (site of most medial femoral condylar pathologic change) of the medial femoral condyle is separated from the tibial eminences. The medial and lateral aspects of the medial tibial condyle are superimposed. The right image is obtained too lateral and at too steep of an angle. The medial femoral condyle is superimposed with the eminences of the tibia.

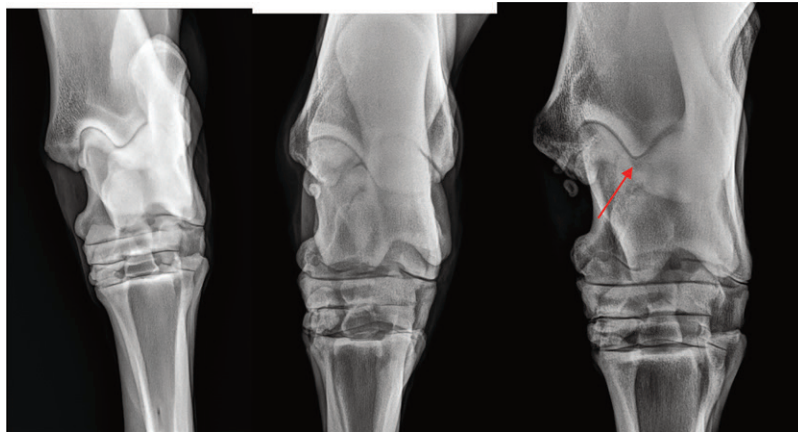


Fig. 6. Dorsoplantar images of the tarsus. The left image is a normal D10L-P. Note the calcaneus is superimposed over the lateral cortex of the tibia, the medial malleolus is highlighted and the distal tarsal joints are well seen. The middle and right images show smooth fragmentation along the medial aspect of the tibiotarsal joint. However, the D10L-P image (right image) highlight the fragmentation along the medial malleolus. There is also an indistinct area of lucency (red arrow) in the proximal talus in the intertrochlear groove seen in the right image, not visualized in the middle image.

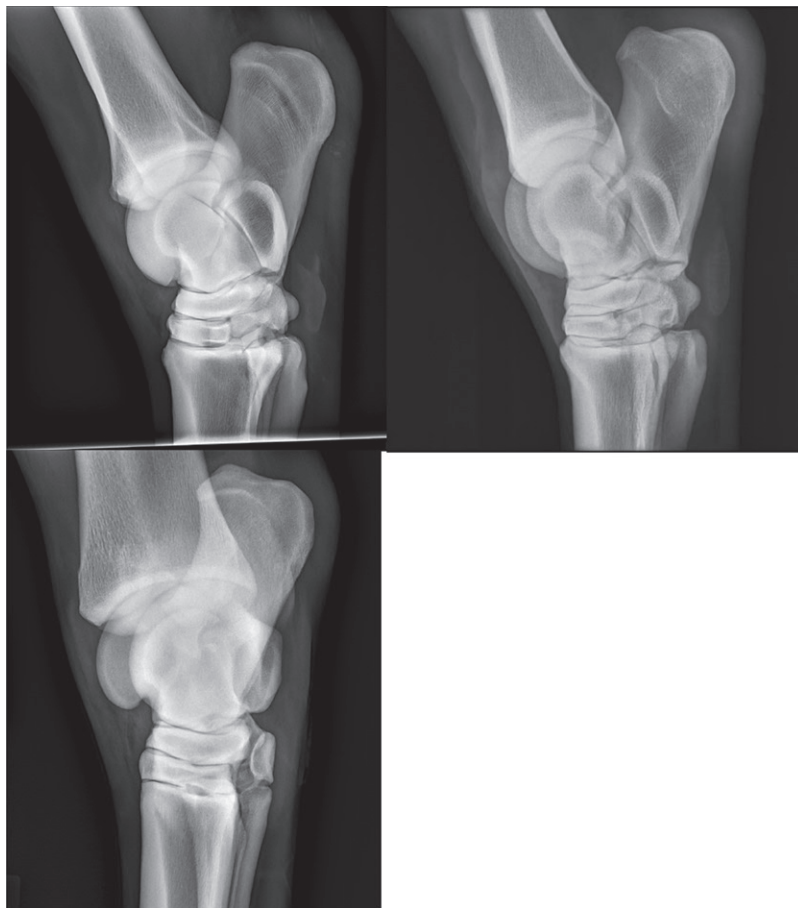


Fig. 7. Images of the tarsus. The lateral image (top left) is well positioned. The trochlear are superimposed and the joints are well seen. This is image was obtained centering just proximal to the head of the 4th metatarsal bone and being tangential to the heel bulbs. The right image is an example of a mildly obliqued lateral image. The x-ray generator is positioned too far dorsal. The bottom left image is a well positioned PLDM-O of the tarsus. The lateral trochlear ridge is partially summing with the medial trochlear ridge. The distal tarsal joints are well seen. This oblique is obtained with a slight proximal angle (5°) in a square standing horse. The image was obtained centering the x-ray beam just proximal to the 4th metatarsal bone and moving plantar approximately 30°.

imposed and the distal joints well visualized. This is performed by centering the x-ray beam at the level of the central tarsal bone. The dorsal-plantar positioning can be judged by palpating the trochlea of the talus. Laying a finger across the trochlea will give you a guide for the position of the x-ray generator. In addition, using the heel bulbs to line up will also help to direct positioning of the x-ray generator in a cranial-to-caudal fashion. The most common error in positioning is obtaining the radiography too far dorsal. This will project to the medial trochlear ridge dorsal to the lateral trochlear ridge (Fig. 7). Failing to be tangential to the distal joints is typically a result of beam angle. More often than not, the beam is angled slightly proximal, or up the leg. This is typically secondary to horse stance (wide base). Correction can be achieved by angling slightly distal, or by repositioning the leg. The image highlighting the dorsolateral and plantaromedial surfaces of the tarsus is generally referred to as the Dorso 55 medial-Plantarolateral oblique (DMPL-O), suggesting that the image is obtained with the beam on the dorsomedial aspect of the joint. However, it is typically easier and faster to transition from lateral positioning to Plantar 55 lateral-Dorsomedial oblique (PLDM-O) positioning, by staying on the same side of the horse rather than adjusting to shoot from underneath the horse with a DMPL-O projection. Ideal positioning of the PLDM-O should partially superimpose the medial trochlear ridge with the lateral trochlea, “split the nose” so to speak (Fig. 7). Often a slight (5°) plantarolateral distal to dorsomedial proximal angle is needed to be tangential to the distal tarsal joints.

Radiographic examination of the neck has seen a dramatic increase in frequency in recent years. Unlike the distal extremities, the radiographer cannot see the x-ray detector on the opposite side of the neck. This creates positioning problems and often results in images with one vertebral body or facet joint that is not centered on the x-ray detector. Furthermore, the articular facets on the lateral radiographs may not be perfectly superimposed, which can lead to interpretation errors. However, if a moment is taken to palpate the transverse processes and apply white tape to these sites, this can serve as a guide to detector placement and x-ray generator focus (Fig. 8). Centering just proximal to the transverse process will render well-positioned radiographs, when the horse’s poll is in line with the withers. Articular facets at the cranial and caudal aspect of the plate may not be superimposed, however, due to beam divergence or parallax. This issue is typically exacerbated with the short film focal distance used with portable x-ray generators. Symmetrical anatomy of the neck can make lesions difficult to lateralize. Oblique radiographs obtained in a left/right 45–55° ventral to right/left dorsal fashion can help localize lesions⁵ (Fig. 9). The x-ray generator is typically centered at the jugular furrow and the x-ray detector is placed with the transverse process



Fig. 8. Tape has been applied to the skin at the level of the transverse processes. The transverse process of the 3rd cervical vertebra is typically the 1st process easily palpated. This 3rd cervical transverse is ventral to the C3–4 articular facet. Moving caudal the transverse processes are centered on the vertebral body. Centering the x-ray just dorsal to the transverse process should center the vertebral body and allow for well-positioned radiographs.

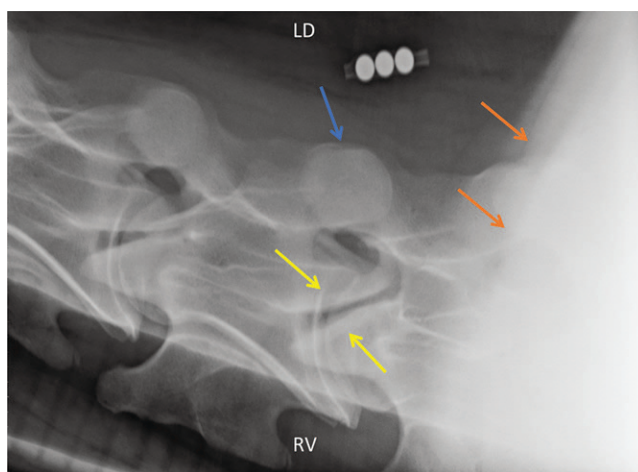


Fig. 9. A left 55 ventral-right dorsal oblique radiograph of the caudal cervical spine. This highlights the left dorsal and right ventral aspects of the cervical spine. The blue arrow is showing the left articular facet joint and periarticular margins. The yellow arrows highlight the right articular facet joint and joint space. The red arrows are highlighting the shoulder musculature, which summates with the C6–7 articular facets joints.



Fig. 10. A well-positioned DP (Dorsal 15–20 proximal-palmar oblique; top right) and oblique (Dorso 45 Lateral/medial 15–20 proximal–palmar medial/lateral–oblique; top left) radiograph of the fetlock. Note that in both images the sesamoid bones are projected proximal to the joint margin and margins of the proximal phalanx. The bottom images are of the same horse illustrating how the sesamoid bones when superimposed with the palmar process can mask lesions (yellow arrow).

centered at the bottom third of the x-ray detector. Radiographic images are named from where the x-generator is located and subsequently where the x-rays enter to where the x-rays exit the neck, and where the x-ray detector is located. In the example of a L55V-RD oblique the left articular facets will be projected dorsally and the right transverse processes will be projected ventrally. Properly labeled, opposite oblique radiographs should be obtained to accurately localize the lesion. Well-positioned oblique radiographs should project one side of the articular facets dorsal and show the intervertebral foramen well. The other articular facet joint will be superimposed over the vertebral body highlighting the joint width. Oblique radiographs obtained with portable units centered at the articular facets at C6–7 are challenging due to the shoulder superimposition. This may be overcome by offsetting the forelimbs, with the leg near the x-ray generator pulled caudally.

Radiographic projections are used to highlight specific areas and document pathologic change. The fetlock is an area with a multitude of pathologic change in which appropriately positioned radiographs make the pathologic change easy to identify. For example, palmar/plantar process osteochondral fragmentation is a common abnormality in the fetlock and depending on the location may be a source of lameness. The oblique views (dorso 20 proximo 45 lateral-palmaromedial oblique and dorso 20 proximo 45 medial-palmarolateral oblique) should show these lesions best. However, if the proximal sesamoid bones superimpose this area, the fragmentation could be easily missed. Ideal oblique and DP radiographs of the fetlock project the proximal sesamoid bones proximal to the joint margin (Fig. 10). The flexed lateral of the fetlock highlights the sagittal ridge to document subchondral bone defects and fragments. Lesions in this area are a documented source of lameness,⁶ and can be difficult to

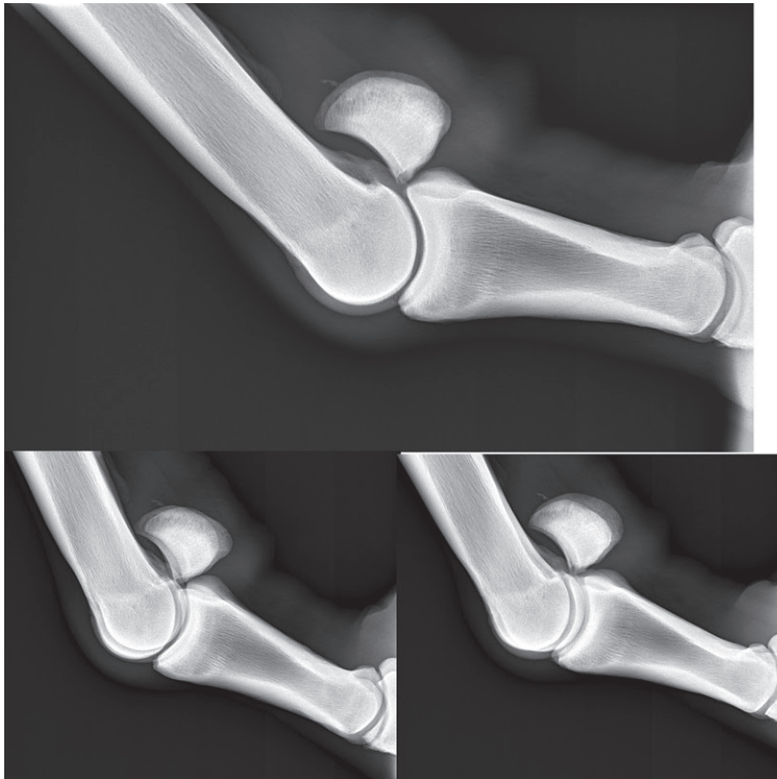


Fig. 11. A well-positioned flexed lateral (top) highlights the mid to dorsal aspect of the sagittal ridge. The medial and lateral aspects of the condyles should be superimposed. The bottom left image is oblique in dorsal to palmar fashion. The distal aspect of the condyles are at the same level; however, the dorsal and palmar aspects are offset. Note that when the limb is flexed (horizontal to the ground) the x-ray generator angle is oblique (down or up) in relation to the horizontal plane not the dorsal to palmar. The bottom right image is oblique in a proximal to distal fashion. The dorsal aspect of the condyles superimpose; however, the distal aspect of the condyles are offset.

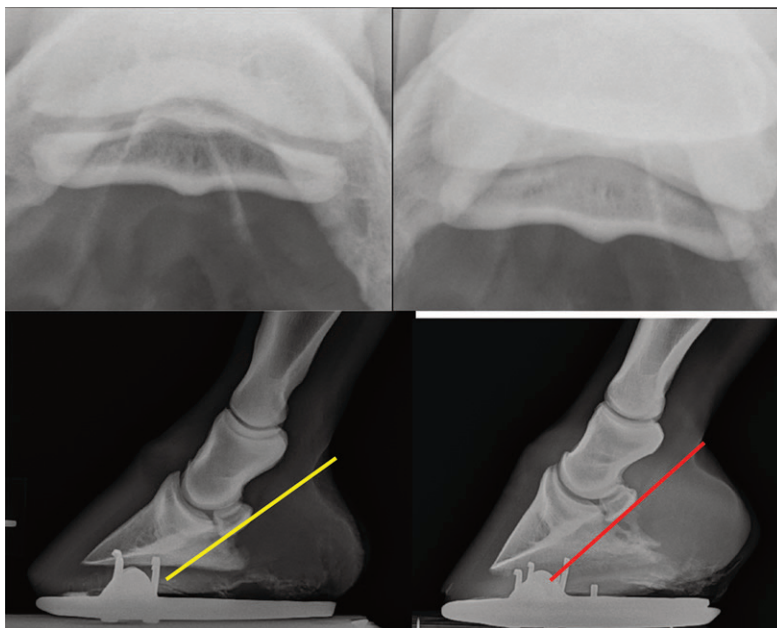


Fig. 12. A well-positioned skyline image of the navicular bone (left image). The joint between the navicular bone and middle phalanx is well seen. There is good corticotrabecular bone definition. The image on the right is the navicular bone of the same limb that is inadequately positioned. The joint between the middle phalanx and navicular bone is artifactually narrow and the corticotrabecular bone is obscured due to summation of the cortex and trabecular bone. The bottom images are well positioned lateral projections of the foot with different conformations. The left image has a foot that has a slightly broken back hoof-pastern conformation. The right image has a foot that has an upright conformation. The yellow line in the left shows a slight less angle needed to be tangential to the navicular cortex, while the upright conformation requires a steeper angle (red line).

fully evaluate on a lateral and DP radiographic projection due to summation with the proximal phalanx. The ideal flexed lateral radiograph should have the medial and lateral aspects of the condyles superimposed. This will allow visualization of the mid-to-dorsal aspect of the sagittal groove without superimposition. Obliquity is the most common challenge with this projection and can superimpose lesions in the sagittal ridge, masking their appearance. More often the obliquity in the flexed lateral image arises from the x-ray generator angled in a dorsomedial to palmarolateral fashion. This may be due to limb positioning or angle of the x-ray generator. Although in the flexed position, the medial and lateral aspects of the condyle are typically more conspicuous and are easier to palpate to help guide the angle at which the x-ray generator should be to acquire a well-positioned radiograph (Fig. 11).

The typical digital radiographic protocol for the foot is four views (lateromedial [LM], DP, palmaroproximal-palmarodistal oblique/skyline, dorso60 proximal-palmarodistal oblique). The skyline projection can be one of the more difficult views to obtain, and is often the go to projection for assessing pathologic change. The lateral projection can aid in obtaining well-positioned skyline radiographs. The angle of the bony column and navicular bone flexor surface can be judged on the lateral images to guide the angle of the skyline. Typically, the angle is 55°. However, in the upright or low-heel-conformed foot it is necessary to change the angle of the x-ray generator to get a well-positioned radiograph. When evaluating for radiographic positioning, you should see the joint space between the middle phalanx and the navicular bone well, and mild summation with the distal phalanx centrally and at the level of the palmar processes. Pseudo sclerosis of the trabecular bone of the navicular bone caused by summation of the flexor cortex can lead to misinterpretation (Fig. 12). Thus, proper positioning is paramount for judging corticotrabeular bone definition. The addition of oblique images (Dorso 60 proximal 45–55 lateral/medial- palmarodistal oblique) may help to highlight the fossa of the collateral ligament and potentially any occult fractures on the D60P images (Table 1).^{7,8} Acute fracture may only be seen on

D60P 50L-P oblique images and should be considered in all lame horses localizing to the foot.

4. Conclusions

Patient preparation and positioning, adequate technique, and knowing how to correct malpositioned radiographs are skills in achieving diagnostic radiographic images (Table 1). Taking a moment to assess unintentional obliquity, patient conformation, and stance can reduce retakes and reduce radiation exposure.

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.

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How to Obtain and Use Radiographic Information to Enhance Therapeutic Trimming and Shoeing in Horses

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1. Introduction

Foot-related lameness is one of the most frequently encountered problems in equine practice. Corrective shoeing is a frequently used preventative and therapeutic discipline for the treatment of many causes of lameness.¹⁻³ Digital radiography allows accurate and repeated measurement of certain parameters that are used as an important aid in trimming and the application of therapeutic shoes.¹ The effects of altering hoof angles on distal limb joint angles have been described.^{3,4} Important clinical decisions are made on the basis of measurements of only a few degrees of angulation in magnitude.¹ Adhering to the smallest details when making farrier decisions can enhance success.

Specific radiographic information remains the professional standard when seeking answers for podiatry issues that require mechanical, therapeutic trimming, and/or shoeing. The primary goal for therapeutic applications is to offset the mechanical limitations and enhance the healing environment. Using specific beam/subject/cassette orientation focused on the particular area of interest, the clinician can produce consistent, comparable images that of-

fer the best representation of the soft-tissue parameters, the coffin bone, and the hoof capsule, thus enabling strategic decisions. This information is of utmost importance as a set of reference points for therapeutic trimming and shoeing decisions as they define the interconnectedness of the internal structures with external hoof-capsule characteristics.

The basic physics of radiation supports the low-beam concept. Radiographs are produced by electrons that travel in straight lines. Those being omitted from the center of the focal spot produce the best possible image of the targeted area. The remaining beams diverge from the primary beam relative to the focal point size of the generator and the further they diverge the more oblique the portion of the image furthest from center beam becomes.⁵ Purpose-driven images produced by focusing on the distal hoof capsule offer several advantages over the previously recommended higher beam.

The exact centering of the radiographic beam for the lateral-medial foot projection has been variably described in the literature.¹ Generally, the horizontal beam is centered below the coronary band midway between the dorsal hoof wall and the bulbs

NOTES

of the heel for a lateral view of the coffin bone.⁶ The centering distance from the coronary band is reported at 2 and 3 cm for standard foot examination, or 2 cm proximal to the solar surface for the assessment of distal phalanx rotation, or through the axis of the navicular bone for the assessment of navicular bone disease.⁷⁻⁹

The low beam lateral-medial (L-M) projection produces consistent, comparable images of the soft-tissue parameters that hold valuable information for the veterinarian-farrier team, e.g., sole depth and cup (SD), palmar (plantar) angle (PA), horn/lamellar zone (HL), and digital breakover (DB). The low-beam dorsal-palmar (plantar) (DP) image reveals medial-lateral coffin bone rim balance and indicates whether a higher projection is indicated to evaluate coffin and pastern joint articular symmetry. These particular areas of interest are not distorted by oblique beam travel nor obscured by the shoe. They are of great interest as each can be altered by the rasp, farrier's knife, nippers, shoe style, and placement. The hoof capsule is also altered by conditions such as the effects of the trim and shoe, growth rate and deficiencies, deformities, injury, and pathological disease syndromes.

The information that can be obtained from this low-beam protocol has diagnostic as well as prognostic value and is a reliable means of monitoring the efficiency of therapeutic trimming and shoeing, and preventive foot-maintenance programs. Veterinarians are responsible for obtaining the images that are useful guidelines for the trimming, shoe design, and application. Interpreting the parameters from even a medical standpoint requires good working knowledge of the foot. When those basic requirements are yet to be learned, the veterinarian must rely heavily on collaboration with the farrier. The farrier who has never had the opportunity to learn how to use radiographic information to help him or her fine-tune their efforts must then rely equally on the experience and dedication of the veterinarian.

2. Materials and Methods

Obtaining informative images to enhance therapeutic trimming and shoeing decisions requires two positioning blocks designed with a sagittal and transverse opaque surface marker that defines the ground surface of the bare foot. The height of the blocks should be 10 to 20 mm below the level of the crosshairs on the collimator of the generator. Most generators have laser pointers that have higher-visibility beam locators in bright light than the light-source crosshair. However, the laser pointer does not remain centered and requires maintenance alignment using the set screws on the collimator. The block-to-crosshairs relationship is of utmost importance as it assures consistent beam-to-subject orientation that is of paramount importance for obtaining consistent, and comparable images.

Preparation of the foot for radiographs is required to obtain quality images. The foot and hair on the



Fig. 1. Properly removing debris and cornified imperfection areas can enhance image clarity and helps eliminate artifacts.

coronet and pastern should be free of mud, medication, and other debris to prevent the foreign material from being superimposed over anatomical structures that can be misinterpreted as possible lesions, and/or simply obscure areas of interest. The sole, frog, and sulci need to be cleaned with a wire brush for baseline lateral-medial and DP views. Removing all tags, uneven areas, and excess growth from the frog with a farrier's knife helps eliminate artifacts (Fig. 1).

The positioning blocks and the generator should be on an identical and preferably flat plane. The position of feet and blocks may be adjusted relative to any toe-in or toe-out conformation. The foot is placed on the medial edge of the block with the sagittal plane parallel to the linear alignment of the block. This offers zero film-to-subject distance and eliminates unwarranted magnification. The primary beam is centered on the foot midway between toe and heel, perpendicular to the sagittal plane of the foot and perpendicular to the cassette.

A bead of radiopaque paste is placed along the dorsal face of the hoof from the coronary crest to the distal border of the toe for the L-M view (Fig. 2). This opaque marker offers a relatively reliable means of measuring and monitoring the coronary/extensor process distance (CE). Neither the crest nor the actual surface of the dorsal wall is visible without the reference line. A lucent zone appears between the paste and what appears to be the wall surface. The use of paste as a marker has advan-



Fig. 2. Low-beam lateral requirements: the horse is placed on the blocks in a natural square stance relative to the toe-in/toe-out conformation, primarily beam 10 to 15 proximal and horizontal to the contact surface, perpendicular to the sagittal plane and cassette, zero film subject distance, and opaque wall marker along the dorsal face from coronary crest to toe.

tages over other techniques such as using nails, needles, coins, and marking tape to help define the wall surface, given that none of those alternative markers conform to the unique characteristics of the growth ring patterns, which provide valuable information describing the hoof capsule's past history (Fig. 3).

Traditionally, foot-radiography protocols recommended the removal of shoes. This recommendation is still sound when the shoe might be superimposed over the subject of interest. However, the low beam does not superimpose the shoe over any part of the foot, allowing the farrier and veterinarian an unobstructed view of the SD, PA, and DB distance. It is best to leave the shoes on for the baseline views



Fig. 3. Note that the growth ring pattern, actual wall surface, and CE are clearly revealed by the bead of paste along the dorsal face of the hoof.

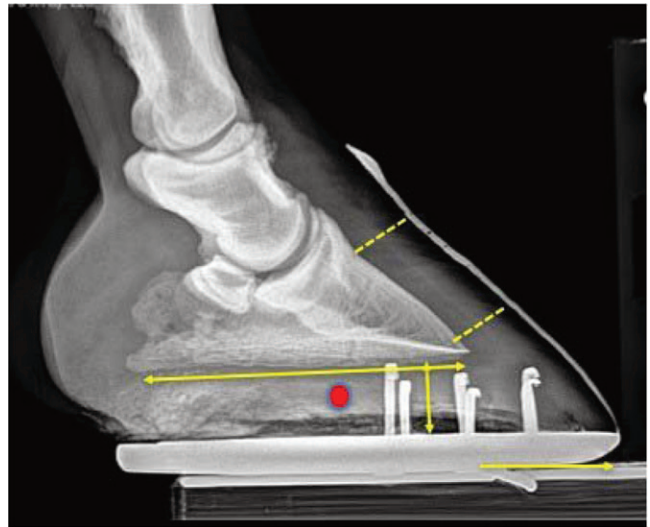


Fig. 4. The low-beam orientation will consistently produce an image revealing one branch of the shoe and the basic information that is paramount for specific mechanical shoeing protocols.

as they offer useful information of the existing relationship of the shoe to the pertinent soft-tissue parameters and overall balance. Performing radiography with the shoes in place can also be useful to evaluate the mechanical relationship of the shoe with the load surface, soft-tissue parameters, and digital alignment.

Taking into consideration the time lapse since the last trim or shoe reset can offer valuable information that alludes to the influence of the pre-existing trim and shoe over the past days to weeks. Recording the exact or approximate date of the last trim or reset can enhance case interpretation, e.g., a SD of 10 mm on a foot shod only a few hours or days may be of less concern than 10 mm of sole on a foot shod 6 weeks previously. When presented with a horse with a very thin sole, for whatever reason, this may not be recognized as such, but a glance at the lateral image with the shoe on can provide valuable information. Awareness of this condition can prevent unwarranted pain and damage to sensitive structures during subsequent shoe removal. Therefore, preparation to protect the vulnerable sole can be made before the shoes are pulled.

The low-beam L-M orientation will consistently produce an image revealing one branch of the shoe and the basic information that is critical for specific mechanical shoeing protocols. To facilitate the correlation of the image information with external landmarks it is helpful to display the image as taken, e.g. L-M view, left feet point left and right feet point right. The DP view should also be displayed as taken. Horizontal flipped images unwarrantedly complicate the mechanical thought process (Fig. 4). Exceptions are feet with >25 mm of SD, pads/shoes, and other devices that elevate the foot and palmar rim above the primary beam that is

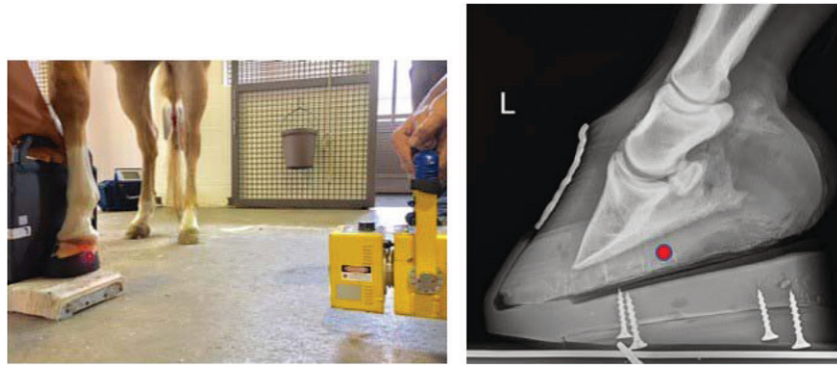


Fig. 5. Significantly increasing the distance between the positioning block and the palmar rim requires the beam to be raised according to evaluate SD and PA.

relative to the positioning block height. When the standard low beam is used in these circumstances, the image reveals one branch of the shoe, but two wings of the coffin bone, even when medial/lateral balance exists. In these cases, compensate for the low beam relative to the increased distance from center of primary beam to the palmar rim, the x-ray machine needs to be raised accordingly (Fig. 5). Otherwise, evaluation of medial-lateral balance, sole depth and cup will be questionable.

The standard low-beam image is considerably different from the recommended high beam, which produces an undistorted image of the navicular bone and coffin joint but grossly distorts the distal anatomy that is of primary interest (Fig. 6). The high beam invariably reveals two branches of the shoe and both wings of the coffin bone unless remarkable medial-lateral imbalance is present. In the case of remarkable listing, the wings can appear superimposed due to beam divergence. High-beam lateral images that reveal superimposed wings of the coffin bone can lead one to believe that good palmar-rim balance exists when the foot actually is remarkably out of balance and most often listing medially (Fig. 7).

The low-beam DP view reveals the load planes of the palmar rim along with associated soft-tissue

parameters and coffin-bone characteristics; the resulting image also alludes to joint-plane symmetry, which may be an indication for subsequent higher-beam studies at the level of the joint surfaces. To avoid unwarranted misrepresentation of the position of the bone within the capsule and symmetry of the joint surfaces, the horse should be positioned in a natural load stance with head held in line with the sagittal plane.¹

There are several parameters that are important for the farrier to know, as each is altered with every trim and shoeing procedure (Fig. 8). When pathology and imbalance require specific mechanical realignment, it is vital that farriers know what they have to work with and what, if any, limitations need to be addressed before they start. The SD is defined as the vertical distance between the palmar/plantar margin of the coffin bone and the outer surface of the sole. It is routinely measured at the distal tip, or apex, of the coffin bone, e.g., SD of 10 mm and 3 mm cup of foot can be recorded as SD 10/3. When farriers are well aware of the distance between the sole and the coffin bone, it helps them avoid removing or leaving too much foot.

The PA is measured by one line along the palmar rim of the wings and one along the ground or load surface of the capsule. A bead of paste placed on

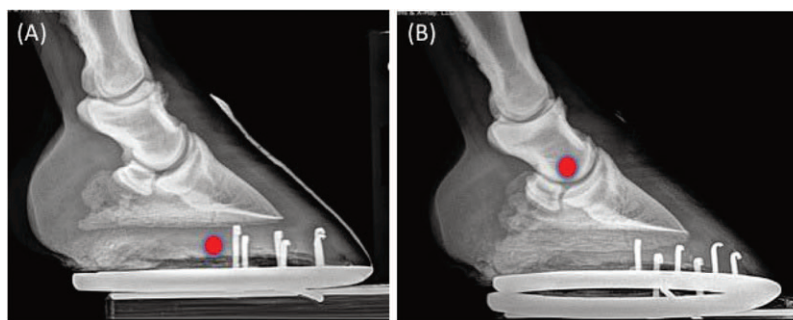


Fig. 6. A, Low beam, horizontal to the ground, centered to the foot, 10 to 20 mm above the positioning blocks, perpendicular to the sagittal plane and cassette, producing one branch of the shoe. B, High beam, positioned just below the coronary band, producing two branches of the shoe and both wings with an illusion of media/lateral imbalance.

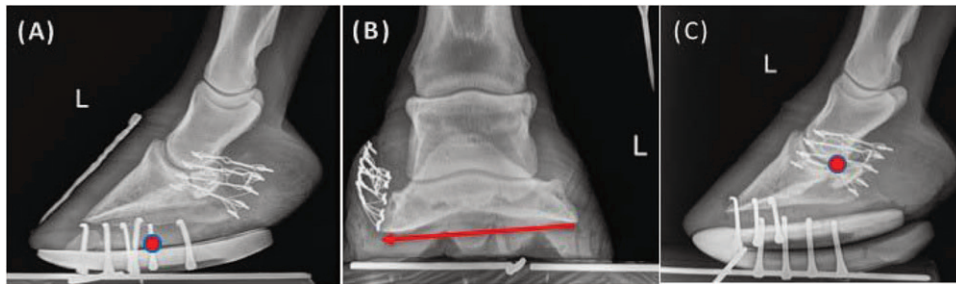


Fig. 7. A, Low beam: note two wings. B, Note medial listing. C, High beam: note superimposes the wings, the result of diverging electrons.

the skin-frog junction and another on the apex of the frog can allude to the plane of the palmar rim, which is revealed on the L-M image. This image is of paramount importance for specific trimming and shoe decision making (Fig. 9). When the apex is eroded or altered by load and/or pathology, the PA is referenced from the palmar rim line along the straightest part of the wings (Fig. 10). When the shoe type/design alters the PA, it is referred to as the “PA with the ground” (Fig. 11).

The DB is measured by dropping a vertical line from the apex to the ground surface, and forward from this line to the point where the hoof or shoe does not contact the ground surface. This area increases with growth between resets and invariably decreases when the foot is trimmed.

The PA, SD, and DB are invariably altered with every trim and shoe application, as the farrier removes ground surface wall and sole. When these parameters are unknown and the toe appears remarkably out of proportion with the crushed heel, the dorsal face is often backed up to reduce break over and hoof angle in an effort to give the foot a better-balanced appearance (Fig. 12). This practice can be counterproductive and unfortunately has very little if any significant positive effect. When specific mechanical goals are to be achieved it is important that the farrier be well aware of these parameters, especially when the horse is faced with career and life-threatening issues (Fig. 13).

The bone angle (BA) holds interest for the farrier and veterinarian even though their interest is quite different. This angle is measured by a line along the most appropriate dorsal face of the coffin bone intersecting with another along the palmar rim of the wing (Fig. 14). Many believe all feet are identical and should therefore look alike and match outside, but this is a misconception, at best. Bone angle can vary from 35° up to 65°, and often vary 5° to 10° between feet on the same horse.¹⁰ The toe angle and basic hoof stereotype is directly influenced by the bone angle. Therefore, farriers should be aware of this radiographic information when they are expected to match hoof angles that simply cannot be matched due to different bone angles.

The bone angle is also of interest to veterinarians who are considering inferior check-ligament desmotomy for the treatment of a club foot. The bone angle within the club foot can be as much as 10° larger than that of the opposite foot. Frequently, the goal of surgery and therapeutic shoeing is to eliminate the “club” appearance by decreasing deep digital flexor tendon tension and lowering the overall toe and heel angle. However, a 60° bone angle and a 0° PA club foot following surgery and shoeing still leaves the hoof angle a noticeable 10° different from the opposite foot, which most likely has a natural 50° BA and zero PA. This brings into question the validity of the decision to perform surgery when there is an initial low PA and 60° BA.

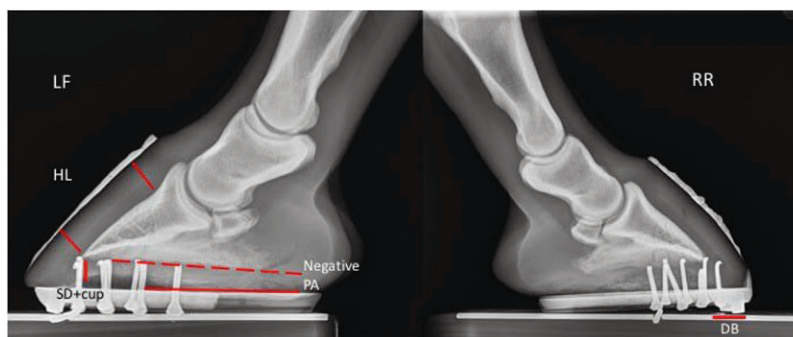


Fig. 8. Low-beam L-M images: Reveal parameters of great interest for the farrier as they are altered by trimming and shoeing. Left feet should be displayed left, and right feet right. Note the lucent zone between the opaque paste and visible wall surface.

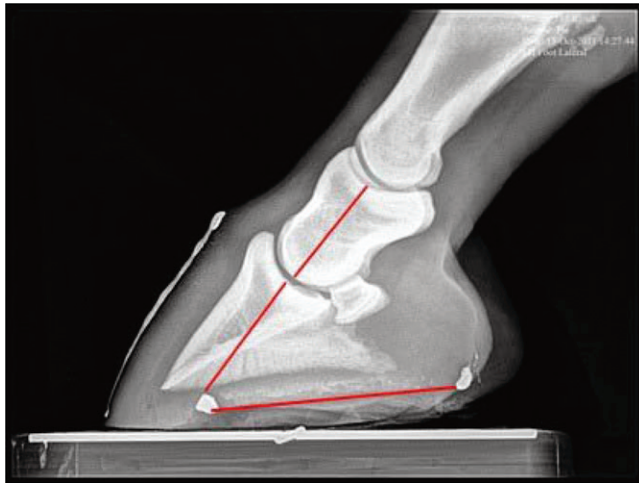


Fig. 9. Radiopaque paste placed on the skin-frog junction and apex of the frog allude to the PA plane. This aids specific trimming goals and shoeing decisions.

Other parameters of critical importance for a veterinarian's interpretation of the overall health, balance, and ill effects of various pathological foot syndromes include HL zone, dermal/epidermal (DE) line, coronary band/extensor process distance (CE), and tendon surface angle (TSA; Fig. 15).

3. Results

Specific beam-to-subject orientation provides tremendous information concerning the relationship between the structures of the foot and ground forces. This information guides the veterinarian and farrier as they make crucial therapeutic trimming, shoe



Fig. 10. When the apex is eroded the PA should be measured along the straightest margin of the wings.

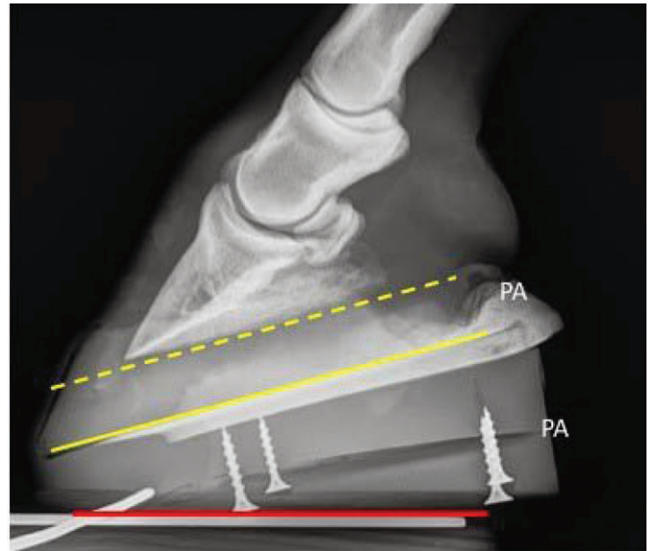


Fig. 11. The capsule PA is zero (yellow), the ground PA 18° (red).

design, and placement decisions. The detailed protocol offers the veterinarian and farrier a reliable means of monitoring any alteration of or changes to the parameters described when assessing the progress/regression of the issue. In addition, this protocol allows close scrutiny of the efficiency and mechanical factors of the chosen therapeutic trimming and shoeing. Radiographs made throughout the specific trimming and shoeing process have enhanced the application and success of many complex podiatry cases. The radiographic guidelines extrapolated to evaluation of the exterior hoof capsule make possible a more accurate means for the veterinarian and farrier to know precisely what there is



Fig. 12. Note how much wall has been removed in an effort to improve the appearance of the crushed heel.

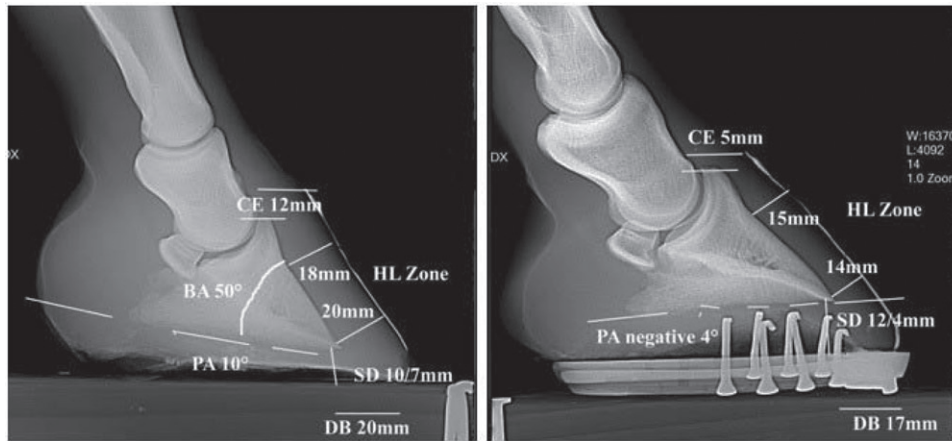


Fig. 13. Note the basic parameter information that can be consistently obtained from the low-beam projection.

to work with and a realistic roadmap for them as they pursue proposed goals.

Post-shoeing images are standard protocol for many vet-farrier collaborations. Radiographic evidence that confirms the trimming and shoeing goals were achieved is multipurpose. These images become the new baseline reference and are paramount documentation for farriers and veterinarians to gain a better understanding of the finer details that are required to mechanically make their job more precise in an effort to enhance the healing environment (Fig. 16).

This disciplined protocol significantly improves the standard of care for podiatry cases by offering detailed information required for specific therapeutic trimming and shoeing. Farriers have developed more confidence with complex cases by increasing their knowledge and skills through radiographic information that enables them to visualize what they have to work with and how well they can follow their goals.

Veterinarians who have adopted this protocol also have gained knowledge, confidence, and skills as they become more involved with searching for useful information that before was not available to the team effort. Formerly generic recommendations, such as to raise or lower the heel, back the toe up, or

tip the inside can now be replaced with more specific reference points and parameters, and more favorable results can be expected as the farrier and veterinarian become more aligned with basic podiatry principals. The odds for success are greatly improved when farriers use radiographic information as it relates to their respective task at hand, and the veterinarian has working knowledge of the therapeutic trimming and shoeing process.

Specific radiographic information described should be utilized by the veterinarian and farrier with a team approach. A well-made strategic plan based on the basic mechanical requirements of the foot can greatly improve the outcome and success of many podiatry cases. The case of the club-footed foal and the chronic laminitis case with coffin-bone sole penetration are some of the typical examples of how radiographs can help the farrier and veterinarian discover the unique relationships that are hidden within the hoof capsule, identify the unhealthy areas of the foot, and proceed to design and execute an efficient mechanical plan to achieve the proposed goals (Figs. 17, 18, and 19).

4. Discussion

Traditional basic radiographic views are informative for other areas of the foot, but they are of limited

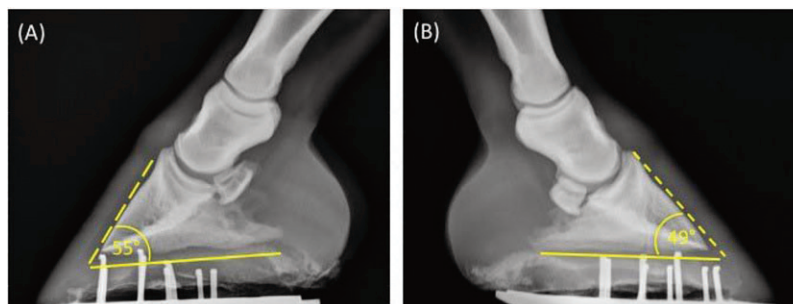


Fig. 14. Typical mismatched feet: note bone angle: A, note 55° bone angle. B, 49° bone angle.

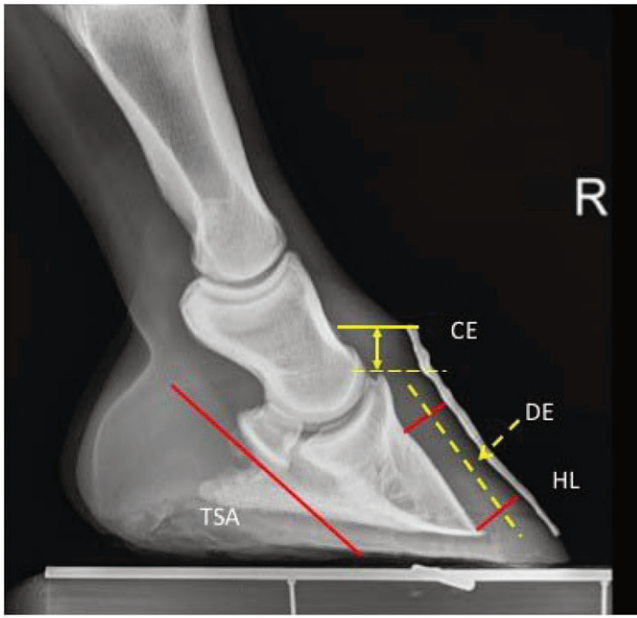


Fig. 15. Soft-tissue parameters that can help confirm a diagnosis and suggest mechanical shoeing applications: TSA, CE, HL, DE.

value relative to the challenge of understanding the mechanical requirements and complementing the application of therapeutic trimming and shoeing. High-beam foot images offer the best representation of the navicular area and coffin joint but grossly distort the palmar rim, sole, cup, DB, and HL zone. The high-beam projection superimposes the shoe branches over the areas of concern, making it virtually impossible to accurately evaluate them. Image distortion can lead to misrepresentation and an incorrect diagnosis. Therefore, we must modify our radiography protocol to get the most accurate image with the best information on which to base our interpretation, our mechanical evaluation, and our ultimate decision making. The option of using low-beam orientation focused on the particular area of interest can produce consistent, comparable images that offer the best representation of the soft-tissue parameters, the coffin bone, and hoof capsule, enabling efficient and strategic decisions. This information is of utmost importance as a reference point for therapeutic trimming and shoeing.

Caution is due as all measurements are subjective at best, especially those referenced along irregular anatomical surfaces. Linear reference points sim-

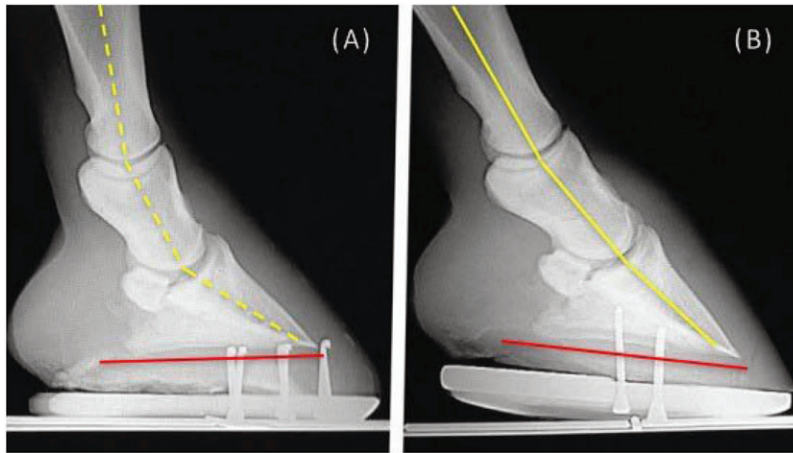


Fig. 16. A, Note the negative PA and digital bone alignment. B, Increasing the mechanical benefits resulted in a zero-capsule PA and 6° ground PA with improved digital bone alignment.

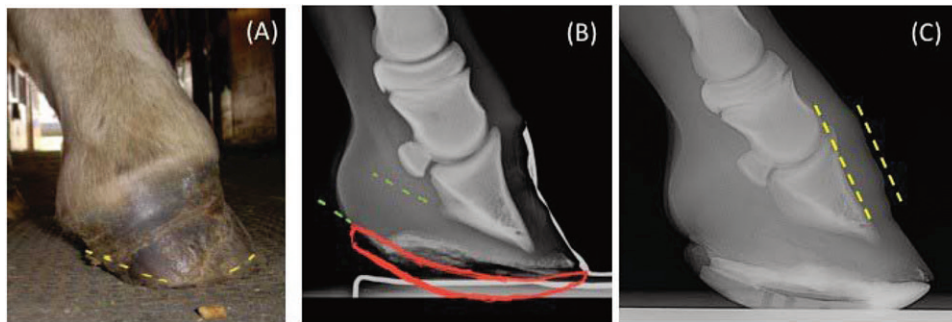


Fig. 17. A, A 1-month-old foal with grade 3 club foot. B, The radiographic image used as a strategy blueprint can enhance therapeutic trimming and mechanical shoeing decision making. C, Evidence of SD growth, good bone alignment, and a more parallel hoof wall growth from the coronary band 1 month later.



Fig. 18. A, Horse with chronic laminitis with sole penetration of the coffin bone. The precise trim requirements are indicated on the low-beam image (dashed red lines). B, Desired bone alignment achieved post deep digital flexor tenotomy (yellow lines). Antiseptic solution soaked gauze over the unloaded apex of the exposed corium due to the penetrated coffin bone (red arrow). C, Evidence of outcome achieved 4 months later based after designing and executing an efficient mechanical plan to achieve the proposed goals.

ply do not exist in nature. Therefore, it is still impossible to have an undisputed absolute, accurate measurement. All measurements are made of two elements; proficiency, and how well we control the human error factor. Therefore, all are subjective and at best only reasonably accurate.

Although radiographic examination of the equine foot has made tremendous advancements in the past decade allowing us to better understand normal anatomy and how it relates to lameness, the use of radiographic information of the foot to enhance therapeutic trimming and shoeing remains a challenge for many practitioners. The radiographic anatomy is complicated by superimposed horn capsule, bone and soft tissue, as well as areas of different air density.

The veterinarian and farrier must be well informed of the radiographic information that relates directly to his or her task of achieving the proposed mechanical goals. The widespread use of digital radiography has enabled the practitioner to obtain high-quality resolution and detailed images that are immediately available for the collaborating vet/farrier team. Computer technology advantages such as smartphones and/or tablets are common tools for

the progressive vet/farrier team, making it possible for them to discuss pertinent details relative to radiographic images, photos, and proposed goals when schedules and commitments are not compatible.

However, many practitioners have little or no experience of the farrier trade or its skills; they find it difficult to be aware of the information that can guide the eyes and hands of the farrier. Likewise, many farriers have not had the opportunity to learn how to comprehend the radiographic information that is of utmost importance to their task and responsibility, and have historically tried to understand and interpret grossly distorted images that relate to their role and responsibility.

Some practitioners may have limited experience with the radiographic procedure and patient positioning for exams that produce consistent comparative images of specific areas of interest for therapeutic trimming and shoeing. Using the traditional high-beam orientation to examine the entire foot has led to misrepresentation and misinterpretation and has handicapped the efforts and outcome of therapeutic goals and treatment protocols. The veterinarian's choice of beam orientation is of para-

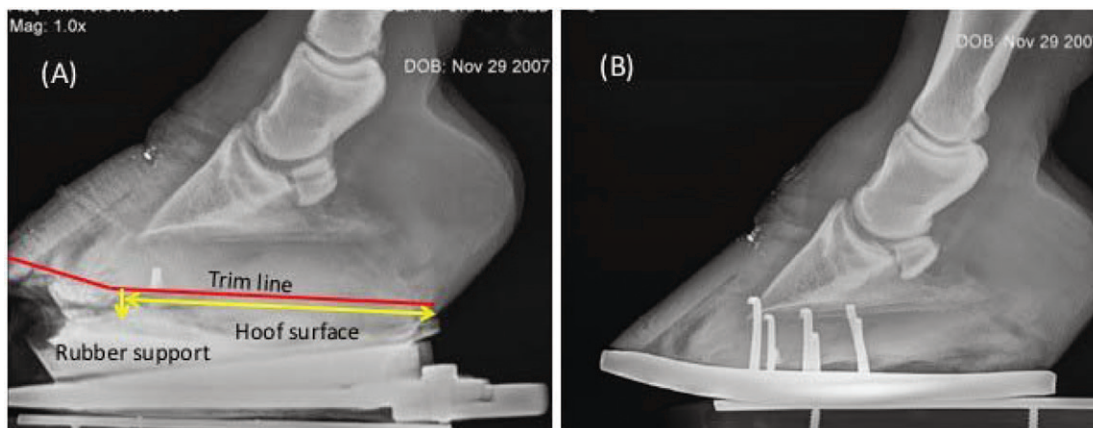


Fig. 19. A, Excessive sole growth 4 months post tenotomy is very deceptive for the farrier without the benefit of radiographic guidelines extrapolated to the hoof. B, Post-shoeing radiographs are just as important as the pre-shoeing examination as they confirm the proposed goals were met and become the new baseline for comparative exams.

mount consequence for the interpretation of soft tissue and bone pathologies.

The mechanical influence on the horse's foot of trimming and shoeing for therapeutic purposes is poorly understood by some farriers and veterinarians as traditional methods have dictated trimming and shoeing to mimic a healthy, balanced foot regardless of the issue, and without consideration of the forces within the foot that influence vital growth centers. By taking the standard recommended radiographic views a step further and helping the collaborating professions learn how to obtain and use this specific radiographic information, we have developed a higher standard of care that enhances well-informed therapeutic trimming and shoeing decision making.

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.

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A Review of Rear Hoof Imbalance and the Effect on Rearlimb Lameness

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Rear hooves may present with broken hoof axis, underrun heels, or medial lateral imbalance. Unlike front feet where these imbalances most commonly cause foot pain, in the rear feet the changed biomechanics cause pain higher up the limb. Addressing rear hoof imbalance should be as important to treat or prevent lameness as it is in the front leg. Author's address: Turner Equine Sports Medicine and Surgery, 10777 110th Street, Stillwater, MN 55082; e-mail: tracyturner1953@gmail.com. © 2017 AAEP.

1. Introduction

The effect of hoof imbalance on fore limb lameness has been well documented. However, rear limb imbalance and its effect on lameness has largely been ignored. The purpose of this paper is to discuss the common hoof imbalances that have been described in the rear hoof, compare those to the forefoot, discuss possible pathophysiology, and finally discuss the effect these rear hoof imbalances have on lameness of the rear leg.

Different biomechanics exist between the forelimb and rear limb. Also, rear hoof biomechanics affect the movement (biomechanics) of the upper limb perhaps and these alterations in biomechanics can result in lameness.

Only three types of hoof imbalance have been described for the rear hoof compared with the front feet, which minimally has at least six.¹ The rear feet develop dorso-plantar imbalance, under-run heels, or plantar surface imbalance, as well as medial-to-lateral imbalance. Unlike the front feet, contracted heels are very rare problems as are horses with mismatched rear feet. It is not that

this cannot occur but the incidence seems to be so low as not to be important. Finally, in the front feet, small hoof-to-body size is a significant problem with important prognostic implications, but it has yet to be recognized in the rear feet. Generally, the rear feet are smaller than the front feet and there are no formulas to evaluate this parameter in the rear feet.

2. Broken Hoof-Pastern Axis

This is the most common rear limb hoof imbalance.¹ The hind hoof is normally slightly more upright than the forefoot, usually by approximately 5°. But like the front foot the dorsal hoof wall and the pastern should be in the same alignment. Many factors can affect this: 1) Older horses often show fetlock hyperextension due to suspensory weakness (age related) and this in turn causes a broken forward hoof pastern axis. 2) Pain in the front feet can cause the horse to place its feet further under the body. 3) Long toes and under-run heels in the front feet cause a similar postural change. The latter two postural changes cause the heels in the rear feet to be overloaded and subsequently retards the

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growth of the heels. The heels are the first part of the hoof to distort.

Unlike the forelimb where hoof imbalances most frequently lead to foot pain, rear hoof imbalance causes problems higher up in the limb.² A broken back hoof axis with a negative solar angle is the most common hoof imbalance of the rear foot.¹ This imbalance causes the hoof to stay on the ground longer than normal. Further, the strain on the deep flexor will be markedly increased over normal before heel lift. This can lead to many lameness issues. The most serious problem is tenosynovitis of the distal tendon sheath. Although not the most common lameness caused by this imbalance because of its effect on the deep flexor tendon it is the most serious. This can lead to marked swelling in the sheath, pain, and even disruption of the blood supply to the tendon.¹ The most common lameness associated with this imbalance is tarsitis, inflammation of the hock. In an unpublished retrospective study conducted by the author, the risk factors for horses needing hock injections was evaluated. The negative solar angle was a common risk factor among all horses needing hock injections. This is probably due to this imbalance causing an increased stance time for the limb. In a different study, this imbalance was associated with a high incidence of gluteal pain in horses.³

The hind hooves have a more exaggerated heel-first landing than the front hooves.² During landing the rear hooves slide horizontally after the hoof touches the ground. At midstance the coffin joint is maximally flexed and maximal extension occurs at the termination of stance. Therefore, anything that increases the terminal stance phase will increase joint extension and therefore dorsal rim pressure on the joints. It is possibly the extra work of the flexor tendon muscle and increased strain on the tendon to overcome the negative solar angle of the coffin bone that causes the stress and damage within the tendon sheath. In addition, it is likely the increased stance phase and increased dorsal rim pressure on the tarsus that creates inflammation in the distal tarsal joints.

Correction of this imbalance would seem simple: raise the heels to correct the negative solar angle. However, the author has noted this causes other problems. The increased heel height further exaggerates heel-first landing, increasing the heel pressure plus increased heel height increases heel pressure during midstance.² In addition, this alters the hoof flight and riders have complained that it changes the gait. A different approach would seem appropriate. The author has used radically rockered shoes to improve rollover and reduce tendon strain. This has been beneficial for tendon sheath swelling cases.

3. Plantar Surface Imbalance

Abnormal heel conformation of the hind feet is easy to recognize.⁴ 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. The bulbs of the heels will have a bending appearance and can be seen lying against the shoe palmar to the end of the heel. The dorsal hoof wall begins to take on a “bull-nosed” appearance. Looking at the foot from behind, the frog is situated well below the hoof wall and the frog can be seen to prolapse down between the two branches of the shoe. The frog is generally large from the constant stimulation with the ground.

Upon removing the shoe, the end of the heel of the hoof wall is located well forward from the base of the frog.⁴ The horn tubules will be parallel with the ground. The hoof wall at the heel will be thin, there will be no angle to the sole, and the bars will be absent. The whole frog will be pushed down below the hoof wall. When the foot is placed on the ground, total weight bearing will be placed on the frog and many horses are reluctant to stand on it when the opposing limb is lifted off the ground.

Viewing the ground surface of the foot, there will be a “trough” noted between the apex of the frog and the inner branch of the shoe at the toe.⁴ Hoof testers placed on either side of the heel at the angle of the sole will elicit a painful response. Damage to the heels of the hind feet is often easier to improve than damage to the forefeet, possibly due to the difference of the load encountered on the hind limbs vs. the fore limbs. Three methods can be employed to treat this condition.

First, allowing a horse to go without hind shoes—if possible—for 4 to 8 weeks can be very effective.⁴ This approach can also be used with horses that are resting due to lameness issues. The shoes are removed and the hoof wall at the heels is moved in a plantar direction until solid structures of the hoof wall are encountered. The hoof wall at the toe is lowered appropriately and the edges are rounded. Over the next few weeks, the pressure on the frog will compress and displace the frog until it assumes the same plane as the heels on either side.

If the horse needs to continue in work and wear shoes, a different approach has been described.⁴ The shoes are removed and the heels are trimmed in a plantar direction until solid horn is established. Excess dorsal hoof wall is removed from toe quarter to toe quarter. The goal is to compress the prolapsed frog to have a flat, even plane that includes both the heels and the frog. The back section of a degree pad is cut out to fit over the frog as a mirror image. A thin strip extending across the toe is left attached to the frog wedge and two 4.5 race nails are placed through this strip into the hoof wall at the toe quarters to hold the frog wedge directly over the frog.

An Animalintex self-contained poultice is saturated with water and applied so it envelops the whole foot. It is secured to the foot with a bandage.

The horse is placed in a stall with a firm surface for 24 to 48 hours. During this time, the feet are submerged in a bucket of water a few times to keep the poultice saturated. At the onset of applying the frog wedge, the horse is given 2 g of phenylbutazone because some horses will show discomfort and others may develop a digital pulse. When the poultice is removed, the frog will be compressed between the heels forming a flat even surface that includes the frog and both heels. The horse can be shod immediately, or can be placed in a stall bedded with sawdust for an additional day to let the feet dry out. The frog will be soft and can be shaped further. Any additional horn at the heels can be removed so the heels of the hoof wall are solid and approach the base of the frog—being careful to keep the frog and both heels in the same plane. A shoe can be fitted and applied. The same principles apply when shoeing hind feet as the front, where a line is drawn across the widest part of the foot and the shoe is fitted so the line is placed in the middle of the shoe. In the hind feet, the branches of the shoe may extend marginally beyond the end of the heels. If additional heel elevation is necessary, a wedge pad or a bar wedge can be placed under the heels as long as the shoe is fitted in the manner described. This will concentrate the load under the frog and heels rather than behind the heels, which is the case with a long shoe.

A third approach is to trim the heels as suggested above but trim the front half of the hoof in a different plane.⁴ This maximizes rollover of the hoof. The effect has been to reduce strain on tendon sheaths and the deep flexor tendon but it has not been successful in restoring the hoof capsule.

4. Medio-Lateral Imbalance

Most people find medio-lateral balance more difficult to assess in the hind feet than in the front feet.¹ The balance of the hoof dictates its placement and affects hoof flight.² Because the pelvis, stifle, and hock all have some lateral movement, it is easy for a hoof that has worn uneven or has been trimmed out of balance to cause the entire limb to move out of line. Because of the asymmetrical movement of the hock, the hind limb has a slight rotating action as it moves forward over the foot. This is necessary to ensure that the feet are wider than the forelegs when galloping. In many animals this leads to an unnatural wear on the lateral branch of the hoof causing the hoof capsule to be high on the inside.¹

The author's assessment of rear-limb hoof imbalances has corroborated the high medial observation. The rear feet are much more commonly high medially, in contrast, the front hooves are more likely to be high laterally. This causes change in the horse's stance. The tendency is for the leg to rotate inward and the limb to be placed more medially. In addition, there are effects on the limb in general. With high medial wall, the limb develops a varus defor-

mity and the fetlock, hock, and stifle can each be involved. Many different lamenesses have been attributed to this conformation.² Injury to the lateral branch of the suspensory ligament has been noted.¹ In addition, increased pressure on the inside of the joints can cause lameness of the fetlock, hock, and stifle. In evaluating rear hoof imbalance cases the author has noted an increased association with both distal hock lameness and medial femorotibial lameness.

5. Evaluation of Rear Hoof Imbalance

It is best to assess hind-limb hoof balance with both rear legs bearing weight equally.¹ Hind limbs naturally rotate outward and must be assessed from the front and back of the limb. An imaginary line from the hock should bisect the hoof with relatively equal halves. Frequently, the hoof looks out of balance when the foot is raised. With the foot raised, the hock moves toward the opposite hind limb and the plantar surface of the distal limb rotates outward along its long axis. Attempting to balance the hoof by sighting down the back of the cannon bone is misleading, and will in most instances make the hoof look high on the inside.

The best way to assess hoof balance (in the author's opinion) is to use radiography to evaluate how the bones align within the hoof capsule. The rear feet can be approached exactly like the front feet. However, there are more technical difficulties associated with rear feet. First, it is more difficult to get horses to stand on the blocks with their rear feet. Two, because the rear legs naturally rotate out alignment can be more difficult.

Accurate identification of key points on the foot, allowing for evaluation of dorsal hoof wall and heel angles, sole depth, and medial and lateral wall height, is not always possible, depending on the technique used and the conformation of the foot.³ Digital radiography allows improved visualization of soft tissues; however, accurate identification of the coronary band and heels can still be difficult. Edge burn-through (saturation artifact) at the periphery of soft tissues is a common artifact with digital radiography. This can result in inaccurate assessment of hoof wall thickness. The author has used lower power techniques with digital radiography so the edge burn-out does not occur and the contrast can then be adjusted digitally so that markers are less necessary. But markers are the most reliable identifiers. Rigid metallic markers or barium paste have been used. The goal is to accurately identify the true border of the dorsal wall and contour. The marker should equal the length of the toe and should be contoured to the true shape of the wall. Running a 2-mm bead of barium paste directly over the dorsal median hoof wall, extending from the coronary band to the tip of the toe, allows for accurate identification of the toe length, wall contour, and border, and provides for an appreciation of hoof wall distortion. A halo artifact (Uber-

schwinger) may be seen surrounding the barium, but this will not preclude accurate border identification. Spot marking at the widest point of the proximal (coronary) and distal wall in the quarters, at the proximal and distal wall in the heels, and at the apex of the frog will aid in the evaluation of quarter angles, quarter wall height, heel angle and height, sole depth, and toe-to-heel ratio.

It is crucial that the positioning of the patient, foot, and x-ray beam be accurate when evaluating the foot for the purposes of podiatry.⁵ True assessment and measurement of the dorsal hoof wall and heel angle, sole depth, joint congruity, medial-to-lateral balance, and toe-to-heel ratio is dependent on proper positioning. Slight abduction or adduction of the limb or shifting of weight can cause joint incongruity on the horizontal beam dorsal-palmar view. The horse should be placed on a firm, level footing, with the limbs squarely beneath the horse. Limb conformation should also be evaluated prior to taking radiographs. When placing the foot on the positioning blocks, it is important to allow the foot to position itself as dictated by the limbs conformation (toed-in, toed-out). To reduce magnification, the foot should be placed on the positioning block in such a way that the foot is as close as possible to the cassette or sensor plate.

The lateromedial and horizontal dorsopalmar projections are the most useful views to perform when evaluating the foot for conformation and balance.⁵ Consideration of the area of interest as well as having solid anatomical knowledge of the horse's foot is important when performing these radiographic views.

The lateromedial (L-M) projection is performed with the horse standing squarely on a flat, level surface with each foot on a positioning block of equal height. It is important that the cannon bone be perpendicular to the floor in both the medial-to-lateral and dorsal-to-palmar planes. Keeping the horse's head and neck straight is also important to reduce the influence of uneven loading of any one limb.⁵ Focal-film distance usually ranges between 24 and 28 inches; it is important to be consistent and that once the technique is established, the focal-film distance remains constant. Once the horse is positioned squarely, proper beam alignment and positioning is the next step in obtaining a workable image. If the area of interest is the distal phalanx and the purpose of the study is evaluating foot balance and symmetry, the center of the beam should be aimed 1.5 to 2.0 cm proximal to the weight-bearing surface and midway between the toe and the heel; the beam angle should be parallel with the heel bulbs and the ground surface. This beam alignment will produce a film that shows the medial and lateral solar margins and palmar processes of the distal phalanx superimposed on one another (in the "normal" foot). Any obliquity in the image can be corrected by raising or lowering the central beam to adjust for vari-

ation in sole depth, or adjusting the beam angle in relation to the heel bulbs.

Correct positioning reduces the likelihood of artifactual changes to the joint space that might otherwise be interpreted as joint asymmetry and foot imbalance.⁵ This projection allows evaluation of medial-to-lateral balance and conformation of the foot with observation and measurement of the medial and lateral wall length and angle, and the orientation of the distal phalanx within the hoof capsule. Orientation of the distal phalanx can be assessed by measuring the distance from the articular surface of the distal phalanx to the ground surface; the solar canal can also be used as a reference point, but it is less consistent. Using the solar margin as a point of reference can be variable due to changes that can occur in the bone. In horses with "ideal" conformation, the articular surface of the distal phalanx is parallel to the ground, as is a line between the medial and lateral coronary band and, the medial and lateral walls are of equal thickness, and the distance from the medial and lateral solar margins to the ground are similar. In horses with significant rotation or angulation in the distal limb, the relation of the distal phalanx with the ground may not be as symmetrical. Furthermore, the distal interphalangeal joint space should be approximately even across its width regardless of angulation of the phalanges. It is normal for the medial quarter wall to be at a slightly steeper angle and subsequently measure shorter in length. However, caution in overinterpretation of joint incongruity is recommended, because any malpositioning of the limb or foot can create the appearance of medial-to-lateral imbalance.

Using radiographs to assess the relationship between the hoof and the underlying osseous structures as an aid in assessing foot balance is about developing an understanding of the relationships between the position of the hoof capsule, the angle of the distal phalanx within the hoof capsule, the symmetry of the interphalangeal articulations, and the alignment of the phalanges.

6. Conclusions

Hoof imbalance of the rear hooves should be considered as important as hoof imbalance of the front hooves. Although the imbalances may not cause specific hoof pain they very likely increase the likelihood of lameness farther up the limb. Assessment by radiography is essentially the same as the foreleg. But visual identification is different given that the front leg and rear leg move differently.

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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The Accuracy of Serum Amyloid A in Determining Early Inflammation in Horses Following Long-Distance Transportation by Air

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Serum amyloid A (SAA) is a more reliable indicator for inflammation than monitoring rectal temperature in the traveling horse. The optimal time to perform a SAA reading was at 24 hours post-arrival using a threshold of 35 $\mu\text{g}/\text{mL}$. Authors' addresses: Swiss Institute of Equine Medicine, Vetsuisse Faculty University of Berne, Equine Department, University of Bern, Länggasse 128, Berne, CH 3012, Switzerland (Oertly, Gerber); Epona Biotech Limited, Business Innovation Centre, Institute of Technology Campus, Ballinode, Co., Sligo, F91 WFW9 Ireland (Anhold); and Department of Veterinary Medicine and Epidemiology, School of Veterinary Medicine, University of California–Davis, One Shields Avenue, Davis, CA 95616 (Pusterla); e-mail: marc.oertly@gmx.ch. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Transportation of sport horses increases their susceptibility to infectious diseases. Before, caretakers relied on rectal temperature together with their clinical impression to detect travel sickness. This study's aim was to assess and compare serum amyloid A (SAA) against rectal temperature as an indicator of early inflammation in sport horses after traveling by air. Furthermore, the optimal time to measure SAA was determined.

2. Materials and Methods

One hundred twenty-one Warmblood horses were followed during the Longine Global Champions Tour 2016 to three destinations where the horses flew to compete. Clinical health checks and SAA measurements were taken at four different time points: prior to flying, upon arrival (0 hours), 24 hours post-arrival, and 48 hours post-arrival.

SAA was tested using a stall-side lateral flow immunoassay. Rectal temperature was measured twice a day using a commercially available digital thermometer.

3. Results

Using a cutoff value of 35 $\mu\text{g}/\text{mL}$ SAA, 97.1% sensitivity and 97.2% specificity was achieved in correctly distinguishing between clinically normal and abnormal horses at 24 hours. Positive and negative predictive values were found to be 89.5% and 99.3%, respectively. Conversely, only 2.9% sensitivity was observed using rectal temperature.

4. Discussion

Monitoring SAA in the traveling horse for an early detection of infectious processes can improve the outcome if treatment is initiated early on.

Research Abstract—for more information, contact the corresponding author

NOTES

Acknowledgments

Declaration of Ethics

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

Conflict of Interest

Dr. Anhold is the founder of StableLab which manufactures and sells horse-side blood tests for SAA. The other authors have no conflicts of interest.

Comparison of Foaling Prediction Methods in Periparturient Standardbred Mares

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Prefoaling mammary secretion calcium titration determinations identify the highest proportion of mares foaling on day -1 and day 0 compared with other methods. Authors' addresses: Department of Clinical Sciences, Cornell University, Ithaca, NY 14853 (Diel de Amorim); Atlantic Veterinary College, University of Prince Edward Island, Charlottetown, PE C1A 4P3, Canada (Morrison); Department of Animal Science, Dalhousie University, Truro, NS B2N 5E3, Canada (Montanholi); and Department of Large Animal Clinical Sciences, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, SK S7N 5B4, Canada (Whitehead, Lopez, Card); e-mail: md649@cornell.edu. *Corresponding author; †presenting author. © 2017 AAEP.

1. Introduction

Gestation length can vary greatly between mares and therefore a comparison of methods to predict impending foaling is warranted.

2. Materials and Methods

Standardbred mares (n = 23) ages 5 to 18 years were monitored daily for parturition. Mammary secretions were collected daily starting between 320 and 330 days of gestation and assessed using calcium titration method, digital pH meter, pH test strips, water hardness test strips, and Brix refractometer and compared with a birth monitoring system.

3. Results and Discussion

Sixty-five samples were analyzed from Day -3 to foaling. Significant differences $P < .05$ between prefoaling mammary secretion technologies were found on Day -3, -1, and 0. The calcium titration method

was significantly related to foaling with the highest proportion (94% and 95%) of mares showing readiness to foal on Day -1 and 0, respectively. Birth monitoring resulted in 82% of mares foaling with an alarm, 18% without, and 19% false alarms. The pH determination method influenced the benchmark for readiness to foal. More studies are required to identify technologies associated with impending foaling.

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.

Research Abstract—for more information, contact the corresponding author

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Review of Elective Surgery in the Pregnant Mare

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and Maria R. Schnobrich, VMD, DACT

Anesthesia of the pregnant mare is best avoided but occasionally required. When possible, elective surgery should be scheduled at least 40 days post breeding and prior to day 220 of gestation. Authors' address: Rood and Riddle Equine Hospital, PO Box 12070, Lexington, KY 40580-2070; e-mail: jhubbell@roodandriddle.com. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

The risk of anesthesia and surgery are greater in the horse than in other domestic species with reported incidences of mortality ranging from 0.12–1.6% when elective and emergency surgeries are included.^{1–3} The source of this increased risk has many components including temperament, the cardiopulmonary changes associated with anesthesia and recumbency (particularly dorsal recumbency), and the horse's apparent need to rise to stand shortly after the end of anesthesia.^{1,2} Pregnancy may exacerbate the cardiopulmonary changes that occur during anesthesia because of decreases in cardiovascular and respiratory reserve as the fetus increases in size, especially as the pregnancy nears term. These changes have the potential to affect both the viability of the mare and the fetus.⁴ No large, multicenter study has been undertaken to establish the risk to maintenance of pregnancy in the mare imposed by general anesthesia for elective surgery. Reported foaling rates for pregnant mares experiencing medical and surgical colic episodes provide some evidence of the risk of anesthesia with foaling rates ranging from 53.8–80% depending on the stage of gestation at the time of colic, whether the colic was medical or surgical, and the degree of car-

diopulmonary depression that occurred during the anesthetic period.^{5–8} The purpose of this paper is to provide context for the equine veterinarian when advising clients on the scheduling nonemergent surgery, such as wound revision or cutaneous mass removal, in the pregnant mare.

2. What We Know

Pregnancy in the Mare

Gestation in the mare lasts on average 320–370 days.⁹ The conceptus enters the uterus approximately 6–7 days post ovulation and moves throughout the uterine lumen until day 15–17 when fixation occurs.^{10–12} The initial support of early pregnancy in the mare is through progesterone, produced by the corpus luteum formed from the initial ovulation. At approximately 35 days of gestation the endometrial cups (from the chorionic girdle of the conceptus) form at the base of the pregnant horn and drive formation of accessory corpora lutea, providing additional progesterone until approximately day 100 when placental progestogens maintain pregnancy.^{9,13} Studies evaluating removal of ovarian progesterone have determined that pregnancy in the mare is luteal dependent until approximately 70 days but placental progestogens are sufficient to

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maintain the pregnancy from approximately 100 days until term.¹³ The pregnant uterus enlarges dramatically throughout gestation and the fetus and uterus drop below the pelvic brim at approximately 90–110 days of gestation. The majority of fetal growth occurs in the final 3 months of gestation (day 220 to foaling) at which point the mare's abdomen usually becomes noticeably distended. As the mare's abdomen is expanding, the foal takes up an increasingly larger amount of space growing at approximately 1 kilogram every 2 days.

The mare is relatively fertile compared with some other domestic species such as cattle with per-cycle 15-day pregnancy rates reported between 64% and 80%.^{9,14} Live foaling rate in Thoroughbred mares in Central Kentucky has been reported to range from 62% to 87%.^{14,15} Factors that have been reported to affect the mare's ability to produce a live foal include increasing age, parity, reproductive status, and time bred from foaling.^{9,14} In the several studies examining when pregnancy loss occurs, expected loss rates are estimated at 20% from 15 days to term, and 10–12% from day 40 of gestation to term. It is believed that this increased loss prior to 40 days of gestation is due to increased sensitivity of the conceptus to teratogens, insult, and physiologic stressors that could cause luteal insufficiency.

Effects of Pregnancy on Anesthesia

Little is known about the effect of pregnancy on the cardiopulmonary physiology of the mare.¹⁶ Early in pregnancy in women, tidal volume and respiratory minute ventilation increase. Residual respiratory volume (the amount of air remaining in the lungs at the end of expiration) decreases by 20% in pregnant women near term, reducing their respiratory reserve.¹⁷ Similar changes would be expected in anesthetized pregnant mares in late gestation, particularly when they are positioned in dorsal recumbency. Hormonal changes may have some effect as well. Rabbits administered progesterone require smaller doses of inhalant anesthetics to produce anesthesia and women become more sensitive to the effects of local anesthetics when pregnant.¹⁸

Effects of Sedation on Pregnancy

The majority of anesthetic agents are lipophilic, thus drugs administered to the mare are rapidly transmitted to the fetus. Xylazine, detomidine, and romifidine increase the duration of oxytocin-induced intrauterine pressure waves in normal, nonpregnant mares but acepromazine seemed to have little effect.^{19,20} Xylazine increases intrauterine pressure in pregnant cows.²¹ Detomidine was administered weekly to 10 pregnant mares from day 14 to day 60 of gestation and monthly from then on to term.²² One mare aborted at 167 days and another was euthanized due to torsion of the large colon. Two of the eight foals carried to term had abnormalities (torticollis or bilateral upward fixation of the patella) but the authors con-

cluded that there was no specific adverse effect of the detomidine.

Effects of Anesthesia on Pregnancy

All known anesthetic techniques have the potential to decrease cardiac output, depress arterial pressures, and cause respiratory depression, potentially leading to fetal acidosis, hypoxia, and hypercarbia. No extensive clinical studies of the effect of anesthesia on pregnant mares have been performed, thus we are left to infer risk from experimental studies and from retrospective studies of mares anesthetized on an emergency basis. The largest retrospective study of anesthetic morbidity and mortality in horses showed that mares in the third trimester of pregnancy were at increased risk with two of 16 mares dying of anesthetic-related complications.¹

In an interesting series of papers, Taylor et al^{23–25} used three different combinations of anesthetic drugs to anesthetize ponies for implantation of catheters to study fetal metabolism. One trial used acepromazine, butorphanol and detomidine and ketamine for induction of anesthesia maintained with halothane.²³ A subsequent study examined the use of detomidine, ketamine, and guaifenesin.²⁴ The third study used the intravenous anesthetic propofol after sedation with acepromazine, butorphanol, and detomidine.²⁵ Controlled ventilation with a gas mixture of oxygen and nitrous oxide (used to control the fraction of inspired oxygen) was used to support ventilation in all three studies. The authors noted less fetal acidosis and hypoxemia when the intravenous agents were used instead of the inhalant, suggesting that uterine and fetal perfusion were better with the infusion than with the inhalant. The authors felt that fetal perfusion was better maintained with the guaifenesin-based technique than the other two techniques but direct comparisons could not be made.

At least four studies have examined the effect of colic and surgery for abdominal exploration of mares with colic on subsequent foaling rates. Foaling rates for pregnant mares surviving surgery were 80%, 79.4%, 66.7%, and 53.8%.^{5–8} Potential negative influencing factors on live foaling rates included duration of anesthesia, intraoperative hypotension, intraoperative hypoxia, and perioperative endotoxemia but the results were not consistent across the reports. One study examined the relationship between the timing of the colic surgery and gestational age, finding that mares pregnant 16–39 days at the time of surgery had a lower foaling rate than mares pregnant for greater than 40 days at surgery.⁸

3. Recommendations

There is little to no direct evidence on which to establish the risk of fetal loss in the normal pregnant mare undergoing elective surgery with general anesthesia. Reports of fetal loss in mares anesthetized for surgical correction of colic suggest some

reduction in live-foal rate. Our reading of the available literature suggests that anesthesia performed at least 40 days after breeding should be safer for the foal than anesthesia earlier in the pregnancy.⁸ Placental attachment increases up to 150 days of pregnancy, potentially further reducing risk by optimizing oxygenation. The period of rapid fetal growth occurs after day 220 of pregnancy suggesting that anesthesia for elective surgery might best be performed prior to this time. Thus our recommendation is to anesthetize mares for required elective surgery a minimum of 40 days after conception and prior to day 220 of pregnancy. Oxygenation and ventilation should be supported by delivering increased inspired concentrations of oxygen and controlling ventilation to maximize maternal and fetal oxygenation and minimize maternal and fetal hypercarbia. Arterial blood pressures should be monitored directly and measures taken to maintain mean arterial blood pressure in excess of 70 mm Hg to support uterine perfusion. Nonsteroidal anti-inflammatory drugs and progestagen supplementation should be provided, particularly if the mare must undergo surgery prior to 40 days during the period of luteal dependency in the chance that prostaglandin release associated with the procedure would cause luteolysis.

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.

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Changes in Maternal Pregnane Concentrations in Mares with Experimentally Induced Ascending Placentitis

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Changes in pregnanes in mares with experimentally induced placentitis are primarily due to increased 5- α -reduced metabolites of progesterone rather than progesterone itself. These changes mimic those reported in normal prepartum mares and likely reflect the effect of inflammation on metabolism of pregnanes by the endometrium and placenta. Authors' addresses: Maxwell H. Gluck Equine Research Center, Department of Veterinary Science, University of Kentucky, Lexington, KY 40546 (Wynn, Ball, Esteller-Vico, Squires, Troedsson), and Department of Veterinary Clinical Medicine, College of Veterinary Medicine, University of Illinois Urbana-Champaign, Urbana, IL 61802 (Canisso); e-mail: b.a.ball@uky.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

The endocrine profile of pregnanes in the late-term pregnant mare is complex. Unlike many other mammals, progesterone concentrations in pregnant mares decline around mid-gestation and remain low or undetectable until near foaling. The objective of this study was to compare pregnane concentrations in mares with experimental placentitis ($n = 7$) and control mares ($n = 8$).

2. Materials and Methods

Placentitis was induced via intracervical inoculation of *Streptococcus equi* spp. *zooeconomicus* at approximately 9 months of gestation. Target analytes (progesterone, 5- α -dihydroprogesterone, allopregnanolone,

3- β -hydroxy-5- α -pregnan-20-one, 20- α -hydroxy-5- α -pregnan-3-one, 5- α -pregnan-3- β ,20- α -diol, and 5- α -pregnan-3- β ,20- β -diol) were measured at -8, -6, -4, -3, -2, -1, and 0 days preceding abortion and in gestationally age-matched control mares by liquid chromatography-tandem mass spectrometry. Data were analyzed by a random effects mixed model.

3. Results and Discussion

The interval from inoculation to abortion was 13.4 ± 2.2 days. Concentrations of 5- α -dihydroprogesterone, allopregnanolone, 3- β -hydroxy-5- α -pregnan-20-one, 20- α -hydroxy-5- α -pregnan-3-one, 5- α -pregnan-3- β ,20- α -diol increased approximately 2- to 4-fold in inoculated compared with control mares beginning at 6-8 days prior to abortion ($P < .05$).

Research Abstract—for more information, contact the corresponding author

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Although progesterone increased, changes were relatively small in inoculated mares. Concentrations of 5α -pregnan- $3\beta,20\beta$ -diol were not different in inoculated and control mares. This study demonstrates that changes in pregnanes in mares with experimentally induced placentitis are primarily due to increase in 5α reduced metabolites of progesterone rather than progesterone itself. These changes mimic those reported in normal prepartum mares and likely reflect the effect of inflammation on metabolism of pregnanes by the endometrium and placenta.

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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.

Clinical Application of Hysteroscopic Hydrotubation for Unexplained Infertility in the Mare

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Hysteroscopic hydrotubation using saline improved pregnancy rates in mares that were suspected of oviductal blockage as a cause of unexplained subfertility. Authors' address: Inoue Equine Clinic, shizunai-mena 453-48, shin-hidaka, Hokkaido 056-0001, Japan; e-mail: yinouedvm@gmail.com. *Corresponding and presenting author © 2017 AAEP.

1. Introduction

Therapeutic techniques for potential oviductal obstruction in the mare are limited. Nonsurgical and retrograde treatment for oviductal blockage may be an attractive alternative for current treatment methods. The purpose of this study was to evaluate hysteroscopic selective hydrotubation as a treatment option for presumptive equine oviductal blockage.

2. Materials and Methods

Ten milliliters of saline was flushed retrograde through the oviducts in 28 standing sedated mares that had reproductive histories of unexplained subfertility by inserting a catheter into the uterotubal junction under endoscopic guidance. The catheter was a 200-cm polyethylene tube (1.7 mm outer diameter) that had a 22-G 1.75-in. injection catheter attached at one end and a guidewire for human angiography (0.46 mm diameter, 220 cm long, TERUMO RF-GA18263) was inserted into the catheter. All mares in the study were mated through several cycles (2–20 estrus cycles) by known fertile stallions prior to treatment, with no evidence of

conception. The average number of cycles for each mare prior to treatment was 6.5 ± 4.5 .

3. Results

Saline was successfully infused into a total of 50 oviducts. Twenty-six of 28 mares conceived after the treatment. The average number of cycles for each mare to become pregnant after treatment was 1.8 ± 0.8 .

4. Discussion

This study revealed that hysteroscopic hydrotubation using saline improved pregnancy rates in mares that were suspected of oviductal blockage as a cause of unexplained subfertility.

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.

Research Abstract—for more information, contact the corresponding author

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How to Successfully Recover Intrauterine Marbles and Foreign Bodies Using Manual Extraction or Videohysteroscopy and Endoscopic Tools

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1. Introduction

Recent reports of adverse uterine health effects from prolonged intrauterine placement of uterine glass balls (marbles)¹⁻⁴ prompted a commentary in the *Journal of the American Veterinary Medical Association* that advocated the retirement of such devices to keep mares out of heat.⁵ However, many mares still have intrauterine marbles and marbles are still commonly used in practice. Intrauterine marbles have low efficacy in the suppression of estrus⁵⁻⁷ compared with other methods⁹⁻¹¹ and there are reports of complications such as endometritis, pyometra, and infertility associated with their use.¹⁻⁴ The marbles used in an intrauterine fashion are most commonly either 25 mm (small) or 35 mm (large) in diameter.⁶ Spontaneous loss of intrauterine marbles has been reported,⁶ which is one reason for their ineffectiveness. Marbles that are

retained may however also be ineffective in prolonging the luteal phase in many mares.⁵⁻⁷ The heavier weight of larger marbles may contribute to the difficulty in removing them, because marbles are often located in the most ventral portion of the uterus. This ventral position of a marble in a mare with a dependent, pendulous uterus poses a challenge because the marble must be moved up against gravity in order to retrieve it.⁹ In the authors' experience, large heavy marbles may be undetected during a transrectal ultrasound examination, particularly if the ultrasound probe is positioned on the dorsal rather than ventral surface of the uterus. Because marbles may remain unidentified, second and sometimes third marbles are placed in the mare's uterus.¹

Other foreign objects that have been reported in the uterus include fetal bones,⁸ broken endometrial

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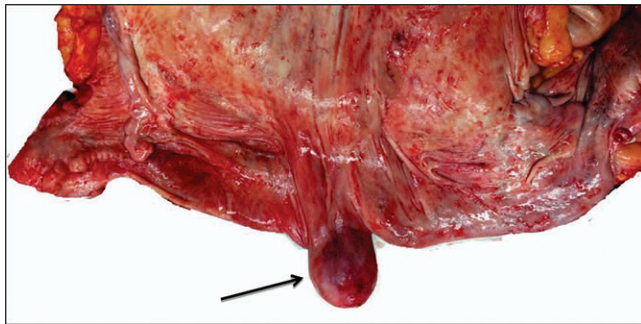


Fig. 1. Postmortem picture of a uterus of a mare that had a marble (black arrow) on the base of the right uterine horn, showing pedunculation.

swab tips,¹² swab caps,¹² and glass shards from marbles.¹ The aforementioned foreign objects have been associated with complications such as pyometra,^{1,3} adhesions,¹ failure to cycle,^{6,7} chronic endometritis,¹ infertility,¹ and abortions.⁴ Therefore, their timely removal is imperative if uterine health and fertility is to be maintained. It has been reported that uterine foreign bodies may be recovered by gentle manual manipulation or with the assistance of hysteroscopy.^{8,12} A detailed description of foreign-body removal using videohysteroscopy and endoscopic tools is lacking.

2. Materials and Methods

History

Owners may request an examination of a mare that had previously had a marble inserted into her uterus because they observe her in estrus, and they assume that the marble has been lost; however, this most often is not the case.¹ In other foreign-body cases the presenting complaint may include failure to cycle, vaginal discharge, or the retrieval of abnormal material such as glass during uterine lavage.¹⁻³

Rectal and Ultrasound Examination

Regarding intrauterine marbles, palpation of the uterus and a transrectal ultrasound examination will usually reveal the marble's presence. In a non-

pendulous uterus intrauterine marbles are readily detected. However, careful transrectal ultrasound examination is imperative in mares with a pendulous uterus. In such cases, the authors recommend that the transrectal ultrasound be performed with the ultrasound probe positioned on the ventral aspect of the uterus, given that heavier marbles are more commonly missed if a dorsal-to-ventral view of the uterus is performed. Marbles may be pedunculated and encased in a pocket of uterine tissue, which is positioned away from the main portion of the uterus (Fig. 1). During transrectal palpation, the examiner should determine whether the marble may be moved within the uterus.

Mapping of the location and estimated size of the uterine foreign object(s) is advised. Foreign objects such as marbles, glass shards, and broken endometrial swab ends and tips are characteristically hyperechogenic and usually cause acoustic shadows (Fig. 2).¹ Hyperechogenic areas on ultrasound should be differentiated from air in the uterus. If multiple small areas of hyperechogenicity are noted, their location and depth in the uterus should be recorded. Mapping the structures in the uterus will aid in identification of these during followup examinations or when recovery of such objects requires more than one attempt. The presence of large amounts of echogenic intrauterine fluid will impair a complete evaluation of the contents of the uterus and fluid evacuation by routine uterine lavage should be performed prior to a foreign-body recovery attempt.

Preparation of the Mare

Following transrectal palpation and ultrasound, the mare's tail is wrapped and perineum is thoroughly washed with gentle soap. It is advisable to sedate the mare if manual extraction will take longer than 20 minutes or if hysteroscopy will be used. A combination of an alpha agonist and butorphanol administered intravenously is commonly used for safety, to prevent straining, and to keep mares comfortable during manipulation. Foreign-body extraction can be accomplished by 1) manual ma-

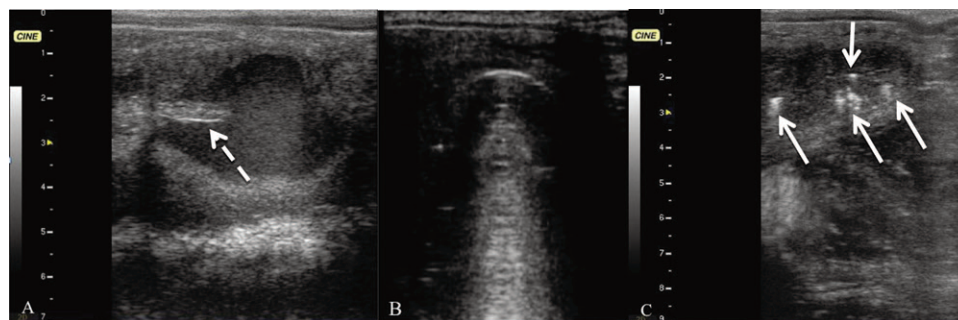


Fig. 2. Ultrasound image of (A), broken swab (dashed arrow) just cranial to the internal cervical os. B, Image of an intrauterine marble with acoustic artifact. C, Echogenic spots corresponding to glass fragments (white arrows) embedded in the endometrium.

nipulation, or 2) videohysteroscopic retrieval using endoscopic tools.

Manual Removal of Foreign Bodies

Recently, broken swab tips are usually located in the uterus just ahead of the internal cervical os, and retrieval should be attempted using a transcervical approach. The mare's perineum should be cleansed and her tail wrapped. The examiner should use a sterile lubricated rectal sleeve and the hand is introduced into the vagina and the fingertips are passed through the cervix. Digital palpation around the internal os of the cervix is performed to identify the swab ends or tip. Removal of the broken swab pieces may be facilitated by gentle dilation of the cervix to allow the introduction of two fingers, or a finger may be placed cranial to the swab tip and the tip manipulated backward through the canal. If this manual extraction fails, a routine uterine lavage with saline or lactated Ringers solution via a bivona catheter^a may be performed to remove small pieces. A cytology and aerobic culture of this intra-uterine fluid may be indicated. The retrieved uterine fluid is visually inspected for the missing broken rod pieces or swab tip.

Multiple fragments of the rod or swab tip may be present and may not be accessible using manual removal. If the broken ends remain in the uterus for more than 24 hours substantial endometrial inflammation results. Therefore, in a diestrus mare with a piece for a culture rod or swab foreign body in the uterus it is not advisable to have a lengthy delay in retrieving the pieces, and unlike a mare with a marble, it is not necessary to wait for the mare to come into estrus. Immediate retrieval of these foreign objects is desirable. It has been reported that fetal bones,⁸ swab tips,¹² or glass shards¹ that have been retained in the uterus for long periods of time may be adhered to or embedded in the endometrium and hysteroscopy may be required to visualize them. Endometrial biopsy forceps inserted through the cervix adjacent to the videohysteroscope have been reported as a means to grasp foreign bodies under direct visualization. This is a fast and atraumatic means of retrieving swab or broken rod foreign bodies.^{12,13}

Prior to large foreign-body retrieval such as a marble, it is advisable to plan the retrieval when the mare is in late estrus or to induce estrus using the administration of prostaglandin F₂α. Marble extraction is more readily and easily achieved when the mare is in estrus because the cervix is softer and more easily dilated. In cases where removal is attempted in a mare with a long, tortuous or fibrotic cervix, Prostaglandin E2^b (0.5 mg) cream, or Prostaglandin E1^c (Misoprostil, 200 micrograms) tablets may be ground into a powder and mixed into 3 to 5 mL of sterile aqueous lubricant^d, which is then applied onto and into the cervical canal from 4 to 24 hours prior to manipulation. Prostaglandin E induces a neutrophil influx; therefore, some cervical

discharge may be present.¹⁴ Mares may also be administered 10 mg estradiol 17-β intramuscularly 24 hours prior to retrieval during estrus to facilitate relaxation of the cervix, particularly if the mare is induced into estrus using prostaglandin F2-α, because these mares may have lower estrogen levels.¹⁵ It is also recommended that N-butylscopolamine bromide^e (0.3 mg/kg, IV) is administered to induce rectal relaxation prior to uterine manipulation.

For manual extraction, a sterile gloved hand is used to evaluate the cervix for dilation. If two or more fingers can be advanced through the cervix and the marble is felt with the fingertips, the marble should be grasped and patiently removed. If the marble is unable to be felt with the fingertips or the cervix is not dilated enough to allow two to three fingers introduced, the examiner should manipulate the marble caudally using a rectal approach and attempt to push the marble out of the uterus through the cervix and into the vagina where a gloved hand is used to retrieve the marble. In mares with a pendulous uterus, multiple attempts may be required during a session to retrieve the marble. A two-armed approach is sometimes required in which the examiner uses a transrectal approach to position the marble as close as possible to the cervix and maintains it in that position with one hand while the other sterile hand is placed in the vagina and the fingertips are used to grasp the marble and manipulate it through the cervix. Careful rectal manipulation is warranted due to the risk of rectal injury. The use of sedation and N-butylscopolamine bromide^e (0.3 mg/kg, IV) is advisable. As the two-armed approach to marble retrieval is difficult, hazardous to the mare, and may not be effective, hysteroscopic retrieval is preferable in these cases.

Hysteroscopic Retrieval of Foreign Bodies

The mare's tail is wrapped and her perineum is cleansed. Two operators are required. One operator wears a sterile rectal sleeve and surgical glove, they pass the scope through the cervix, position the videohysteroscope in the uterus, and hold the cervix tightly closed around the scope. The second person operates the controls of the videohysteroscope and passes and operates endoscopic tools. Before beginning the functional capacity of the videohysteroscopic equipment to insufflate the uterus, the equipment should be evaluated prior to the procedure by attempting to insufflate a sterile rectal sleeve using 20 seconds of insufflation with CO₂ or air. If insufflation of the rectal sleeve is not achieved in 20 seconds then an external flow regulated insufflation source^f should be used to add supplemental air flow through the biopsy channel. Good uterine insufflation is necessary to minimize the time needed for the procedure, to fully visualize the uterine body and horns, and to locate the foreign body. Failure to easily visualize the interior of the uterus is almost always related to poor insufflation.

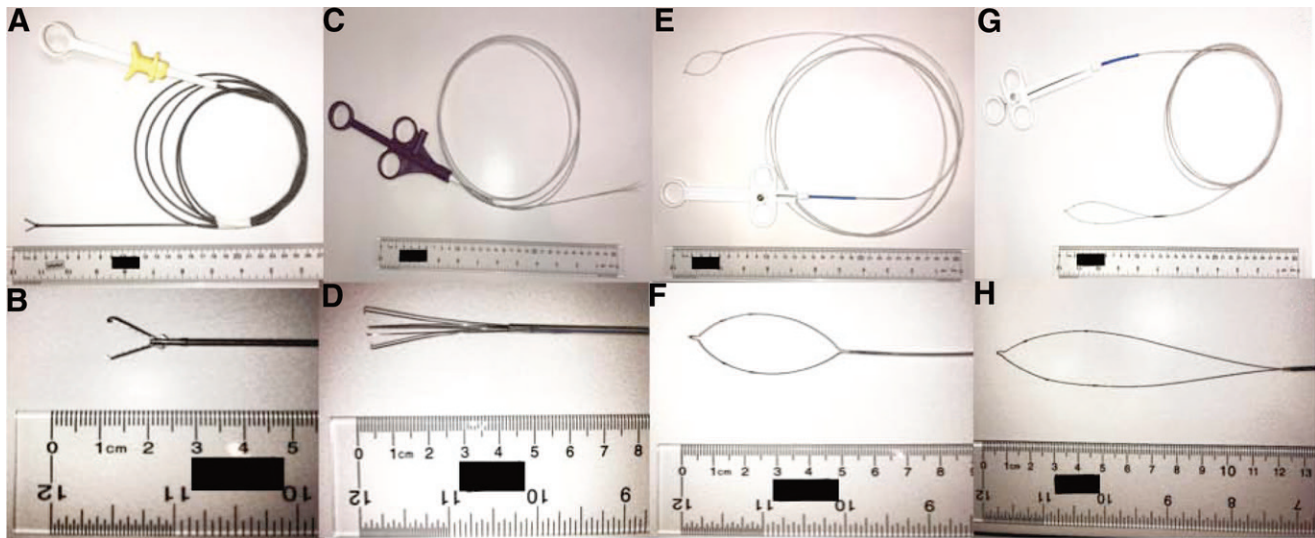


Fig. 3. Examples of endoscopic tools (A–H). Endoscopic tools that can be used for grasping broken swab pieces or glass shards are shown (A–D); flexible snares with loop ends that can be used for grasping marbles are shown in E–H.

Therefore, adequate insufflation is of the utmost importance. In the authors' experience, insufflation works better for retrieval of a foreign body compared with using fluid to achieve uterine distension as there is one less resistance impedance when manipulating endoscopic tools and foreign objects. Fractured or adhered marbles that have been in a mare's uterus for a prolonged time, swab tips, or glass shards embedded in the endometrium are better evaluated and removed with the aid of a videohysteroscope. For videohysteroscopy, a 1.6-m-long video gastroscope or hysteroscope^g with a biopsy portal for introducing endoscopic tools such as flexible baskets snares or tk;4guided wire device are used (Fig. 3). Upon identification of the foreign body, an appropriate endoscopic tool should be passed through the portal of the scope.

Swab tips and broken rod pieces can be removed by passing an endometrial biopsy forceps^h into the field of view alongside the videohysteroscope and then grasping the pieces under direct visualization

with the biopsy forceps^h, or through the use of an ellipsoid cup forcepsⁱ (Fig. 4), a pelican grasper^j (Fig. 3, A and B), or a four-prong grasper^k (Fig. 3, C and D). Other tools used for foreign-body retrieval include flexible oval loop snare^l, jumbo oval grabber snare^m (Fig. 3), four-wire basket retrieverⁿ, and angular basket^o that have multiple size options and should be chosen according to the size and type of object to be grasped.

Recalcitrant adhered marbles may be dislodged by gentle massage per-rectum prior to videohysteroscopy. When manual retrieval of a marble is unsuccessful, the marble may be retrieved using a videohysteroscope^g and endoscopic tools such as a flexible four-wire basket retrieverⁿ, angular basket^o, flexible oval loop snare^l (Fig. 3, E and F), or a jumbo oval grabber snare^m (Fig. 3, G and H). Intact large marbles are most easily removed with a jumbo oval grabber snare^m (Fig. 5) or a large flexible angular basket retriever^o, whereas small marbles are more easily removed with a smaller flexible four-wire bas-



Fig. 4. Videohysteroscopic image of a glass shard embedded in the endometrium from a broken marble (A); and example of the flexible biopsy instrument being used to remove the glass shard (B and C).

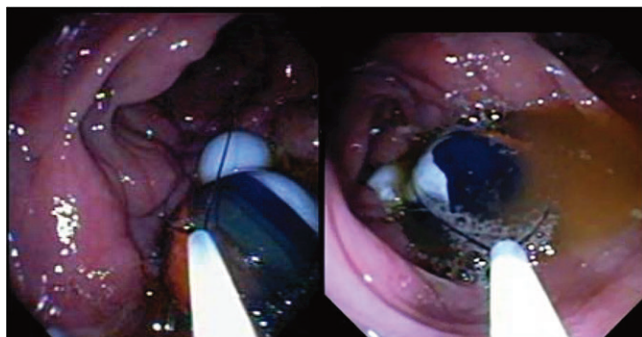


Fig. 5. Videohysteroscopic images of two marbles in a mare's uterus and a flexible wire loop which is shown being used for their retrieval.

ketⁿ or the flexible oval loop snare^l. The basket device is easier to manipulate and secure on top of the marble for its removal. Briefly, the videoendoscope is positioned with the marble in view. A flexible basket snare device is placed through the biopsy port of the videohysteroscope in the collapsed (closed) position and passed into the field of view. The basket is then opened and the open device is advanced and positioned on top of the marble to encircle it. If placement of the basket is successful, the device should be gently closed to allow the basket to be secured tightly around the marble. The flexible basket snare is pulled back to allow the marble within the basket to be held against the tip of the videohysteroscope. The videohysteroscope should be pulled backward into the operator's hand in the vagina so the retrieved marble and videohysteroscope are removed in a controlled fashion from the uterus and vagina. The flexible basket device may also be used to retrieve the glass pieces or to manipulate degenerating glass marbles into smaller chunks. Another endoscopic tool that may be used is the flexible oval loop snare^m or a jumbo oval grabber snareⁿ. However, this tool requires more dexterity when placing the wire loop securely around the marble, given that it easily slides off of the marble's surface. The flexible wire loop is used as a snare and is introduced into the biopsy port of the videohysteroscope as previously described for the basket. The wire loop is passed until it is in the field of view. The wire loop is positioned on the dorsal aspect of the marble and the loop is fitted around the middle of the marble, the wire loop is gently and slowly closed around the marble, until the loop is tightly secured around the marble to avoid it sliding off. The videohysteroscope and the marble are then slowly removed together from the uterus.

Glass shards that are adhered to the endometrium pose a difficult challenge as there may be myriad fragments. Removal may be attempted under direct visualization by passing an ellipsoid cup forceps¹ tool through the biopsy portal and grasping

the embedded pieces, or through an endometrial biopsy instrument^h placed alongside the hysteroscope. The endometrial biopsy instrument, however, often causes bleeding, which may obscure any further fragment removal attempts, and thus is only suitable for cases with a few glass fragments. Chemical curettage of the endometrium may be attempted in cases with large numbers of embedded fragment; however, the success of this as a therapy remains unknown.

Post Procedure

After foreign-body retrieval is completed the uterus should be re-examined with the scope to determine if there is any damage to the uterus such as adhesions, presence of a biofilm, and if there are any other abnormalities. The airflow is then discontinued and the biopsy port of the videohysteroscope is opened to allow the uterus to deflate. Finally, a uterine lavage is performed and other therapies may be administered to aid in removing any iatrogenic contamination, infection, and to treat inflammation. In some cases of retained marbles, videohysteroscopy revealed a biofilm on the endometrium. Additional treatment for endometritis may be required. In cases where glass shards are present fine pieces may be removed through uterine lavage. An endometrial biopsy may be warranted for prognostic purpose under hysteroscopic visualization to evaluate endometrial health in a subsequent cycle.

3. Results

All mares referred for endometrial swab tip removal in three referral clinics have successfully had the foreign body material retrieved either manually, through uterine lavage, or through videohysteroscopy. Fertility of those mares is generally not affected. Hysteroscopy is generally performed for swab or rod retrieval only in cases where multiple pieces are present, if the broken endometrial swab is lodged in the endometrium, or if the cervix is too long, fibrotic or tortuous to allow manual retrieval. Mares with a nonpendulous uterus and with a patent pliable cervix may easily have marbles removed manually. However, mares with long, fibrotic, or tortuous cervix or that have a pendulous uterus may have the intrauterine marbles removed easier and less traumatically with the aid of a videohysteroscope and endoscopic tools. Mares with glass shards from broken marbles can have the luminal and superficial glass pieces removed from the endometrium; however, tiny fine glass shards that are embedded into the deeper layers of the uterus cannot be removed and these may impair the mare's fertility.

4. Discussion

Manual removal of broken endometrial swab tips are more easily accomplished when the cervix is soft and easily dilated, and in most cases the endometrial swab tips are located just ahead of the internal

cervical os. Broken culture rods and swabs may arise due to poor storage or handling of the culture swabs, inopportune movement of the mare, faulty manufacturing, or operator error. The most common errors with double-guarded swabs include inserting the culture swab too far and deep in the uterine body so that there is insufficient space to advance the other parts; and when advancement of the inner sheath and swab are forced, the rod breaks; not stabilizing the swab near the cervix by failing to hold the outer sheath steady in the vagina before advancing the inner sheath and swab portions; or the retraction of the innermost rod prior to the retraction of the interior sheath. For the majority of retrievals of broken rods and swabs no special equipment is needed and in most cases light to no sedation is necessary. Uterine lavage is also effective in many of cases. We have also experienced a batch of swabs where the cotton tips were often left in the uterus, which we believed was due to faulty manufacturing. There are some mares with extremely problematic cervixes that require excessive bending of the swab to gain entrance to the uterus that then compromises the mechanical integrity of the swab. There are thus a few cases that may require videohysteroscopy assistance to retrieve the various foreign bodies. This is preferable to traumatizing the cervix and uterus through repeated unsuccessful retrieval attempts. The disadvantage of videohysteroscopic procedure is the cost and the need for specialized equipment such as the videoendoscope, a biopsy forceps, or the endoscopic tools, such as wire baskets, wire loops, and gasper devices. The major challenge currently is the complete removal of embedded glass shards, which are most likely to permanently affect fertility.

Marbles are not medically approved devices and there are a growing number of reports on the unintended consequences of long-term use including endometritis, pyometra, and infertility.¹⁻⁴ If marbles were medical devices it is highly likely that there would have been a recall. The composition of the marble may also be important, as glass-colored marbles, normally available commercially for recreational purposes, should be particularly targeted for removal. Glass is a porous material and it degrades over time. Borosilicate glass marbles may be more durable; however, a recent examination of a borosilicate glass marble showed surface changes after a 2-year insertion period (Fig. 6). Because marbles are nonmedical devices, are poorly efficacious in preventing estrus, and have led to serious complications, their use should not be recommended, and the removal of marbles should be a priority.

The method used to detect the presence of marbles is important. Experienced practitioners may not detect the presence of a marble in a mare with a dependent pendulous uterus, and in this article we describe how a marble may be pedunculated (Fig. 1)

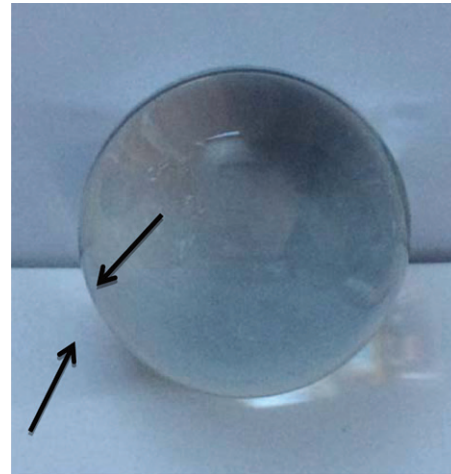


Fig. 6. Borosilicate glass marble retrieved from the uterus in Fig. 1. The marble had been left in the uterus >2 years and shows small imperfections on its surface (arrows).

and found encased in uterine tissue on a stalk, which explains the challenge of marble detection.

There is a paucity of information on the frequency of problematic marble retrieval, sometimes referred to as a marble dystocia. Difficult retrieval is in our experience associated with a dependent uterine location, adhered marbles, or may occur in mares with a fibrotic, or long, tortuous cervix, the length of which exceeds the length of the operator's finger. The use of both arms for retrieval of marbles from the uterus is difficult, challenging, and dangerous. This is due to the heavy weight of the uterus and the heavier weight of the marble, which is often lodged in the most pendulous part of the uterine body, ventral to the cervix, making gravity an additional challenge for expulsion of the marble. The use of videohysteroscopy is warranted in these cases. Smaller marbles can be successfully and more easily removed through a wire-basket device than the loop, and are more easily removed through a cervix that fails to dilate properly. Large marbles usually require the wire loop, wire device or large baskets. Both types of wire devices are found in common use in small-animal referral practices for foreign-body retrieval. Successful retrieval of devices through videohysteroscopy and endoscopic tools requires sedation, specialized equipment, and trained personnel.

Conclusion

Foreign-body material may be manually removed or removed using videohysteroscopy and endoscopic tools. Marbles are nonmedical devices and their intrauterine use should be discontinued. The failure to identify and remove foreign bodies including marbles(s) from the uterine environment may lead to impaired fertility in mares.

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.

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- ^bPrepidil, Pfizer Inc, New York, NY 10017.
- ^cCytotec, Saint-Laurent, Vaughan, ON L4K 4N7, Canada.
- ^dBioLube, MOFA, Ingersol, ON N5C 3K1, Canada.
- ^eBuscopan, Boehringer Ingelheim, St. Joseph, MO 64506.
- ^fVet-CO₂, CO₂ Insufflator, ESS, Brewster, NY 10509.
- ^gVideoscope Olympus GIF-100, 1.6-m length and 1.4-cm diameter, Olympus America, Melville, NY 11747.
- ^hPiling endometrial biopsy instrument, Jorgensen Laboratories, Loveland, CO 80538.
- ⁱVet ellipsoid cup forceps (1.8 mm \times 200 cm), ESS, Brewster, NY 10509.
- ^jVeterinary pelican grasper (2.3 mm \times 230 cm), ESS, Brewster, NY 10509.
- ^kVet four prong grasper (2.3 mm \times 240 cm), ESS, Brewster, NY 10509.
- ^lVet oval loop snare (2.4 mm \times 230 cm), ESS, Brewster, NY 10509.
- ^mVet jumbo oval grabber snare (12.5 cm; 2.4 mm \times 240 cm), ESS, Brewster, NY 10509.
- ⁿVet four-wire basket (2.3 mm \times 240 cm), ESS, Brewster, NY 10509.
- ^oVet nitinol angular basket retriever (3 to 5 cm diameter), ESS, Brewster, NY 10509.

Repair of 40 Humeral Fractures in Horses Less than One Year of Age (1989–2013)

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Intramedullary, interlocking nail (IIN) fixation is an excellent treatment option for young horses with humeral fractures. Authors' address: Department of Large Animal Clinical Sciences, College of Veterinary Medicine, Texas A&M University, College Station, TX 77843-4475; e-mail: jwatkins@cvm.tamu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Outcomes for foals with humeral fractures are historically poor. This study documents outcomes in 40 humeral fractures repaired with an intramedullary, interlocking nail (IIN), alone or in combination with a bone plate. We hypothesized that repaired humeral fractures would have a favorable prognosis for survival and future athletic performance.

2. Materials and Methods

Medical records of horses less than 1 year of age, with humeral fractures repaired from 1989 to 2013 were reviewed. Long-term follow up was obtained through follow-up examination and/or telephone communication.

3. Results

Twenty-five patients, aged 1 week to 9 months (mean, 4 months), and weighing 68 to 295 kg (mean, 177 kg) were repaired with an IIN. Fifteen patients, aged 2 to 12 months (mean, 6 months), and weighing 113 to 377 kg (mean, 242 kg) were repaired

with an IIN in combination with a bone plate (IIN-P). Twenty-six patients were Quarter Horses. Remaining breeds included Thoroughbred (4), Appaloosa (3), Paint (3), Mixed (3), and Arabian (1). Overall, 29 patients (73%) survived to discharge. Long-term follow up on 27 patients documented 25 patients (93%) were able to perform their intended use as adults.

4. Discussion

With appropriate case selection and surgical technique, a good prognosis for survival, and an excellent prognosis for athletic performance in surviving patients, were achieved.

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.

Research Abstract—for more information, contact the corresponding author

NOTES

Comparison of the Use of a Braided Transfixation Suture for Field Castration with Other Castration Techniques

Judith Koenig, DMV, DVSc, DACVS, DECVS, DACVSMR*;
Melissa Sinclair, DVM, DVSc, DACVA; and Ulrike Sorge, DMV, PhD, DACVB

The use of a transfixation suture with 2 polyglactin 910 is a viable option for field castrations under general anesthesia to minimize risk of evisceration without evidence of a higher infection rate after castration. Authors' addresses: Department of Clinical Studies, Ontario Veterinary College, University of Guelph, Guelph, ON N1G 2W1, Canada (Koenig, Sinclair); and Department of Veterinary Population Medicine, College of Veterinary Medicine, University of Minnesota, Saint Paul, MN 55108 (Sorge); e-mail: jkoenig@uoguelph.ca. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Complications with castrations occur commonly and are usually not life threatening, with the exception of evisceration, which is uncommon. Primary closure castration or use of a transfixation ligature alone to prevent evisceration have been recommended.

2. Materials and Methods

We hypothesized that using braided suture material for transfixation under field conditions would not increase postoperative complications compared with a closed field castration technique without suture or a primary closure castration approach in a hospital setting (30 horses in each group).

The following information was collected: age, breed, surgeon, position in surgery, volume of lidocaine injected into the testicle, medications used, surgery time in minutes, recovery score from anesthesia, and suture used. Follow-up postoperative information was obtained by telephone survey and

included the following complications: scrotal swelling, excessive hemorrhage, omental herniation, intestinal herniation, incisional infection, and septic funiculitis.

3. Results

The proportion of postoperative complications was 3.3% of the overall study population, and did not differ statistically between the three groups. The type of suture used (braided, monofilament, or no suture) did not influence significantly the occurrence of postoperative complications in this study.

4. Conclusion

Using a multifilament, transfixing ligature for routine closed-field castration does not result in additional postoperative complications, when compared with a closed-castration technique without ligature placement or a primary closure castration technique in a hospital setting.

Research Abstract—for more information, contact the corresponding author

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Acknowledgments

Declaration of Ethics

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Conflict of Interest

The Authors have no conflicts of interest.

Conditioning Equine Athletes on Water Treadmills Significantly Improves Maximal Oxygen Consumption ($\dot{V}O_2$ max) Measured During a Maximal Intensity Exercise Field Test

Persephone Greco-Otto, BSc*; Stephanie Bond, BVSc;
Raymond Sides, AAS, BMET; Warwick Bayly, BVSc, MS, PhD;
and Renaud Léguillette, DVM, MSc, PhD

It has been accepted that ventilation cannot be altered in horses; however, the present study shows that water treadmill (WT) training increases maximal oxygen consumption ($\dot{V}O_2$ max) through changes in ventilation. Authors' addresses: Department of Veterinary Clinical and Diagnostic Sciences, Faculty of Veterinary Medicine, University of Calgary, Calgary, AB T2N 4N1, Canada (Greco-Otto, Bond, Léguillette); and Department of Veterinary Clinical Sciences and College of Veterinary Medicine, Washington State University, Pullman, WA 99164 (Bayly, Sides); e-mail: persephone.grecootto@ucalgary.ca. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Equine water treadmills (WTs) were initially designed for rehabilitation of injuries, but are also used for conditioning of sport horses. However, the benefits of conditioning horses using WT's are not documented. Therefore, the purpose of this study was to test the effect of an 18-day WT-conditioning program on maximal oxygen consumption ($\dot{V}O_2$ max).

2. Materials and Methods

Nine unfit Thoroughbreds were used in a randomized, controlled trial. Pre- and post-conditioning maximal-exercise racetrack tests were performed using a portable ergospirometry system. Measured outcomes were $\dot{V}O_2$, spirometry, heart rate,

blood lactate, and speed. Six horses worked daily in water at stifle height (water treadmill group-WT) for 18 days. The three control horses worked without water (dry treadmill [DT] group).

3. Results

The workload assessed by $\dot{V}O_2$ was 21.7% greater in the WT than in the DT conditions. $\dot{V}O_2$ max on the racetrack increased significantly by 16.1% from pre- to post-conditioning in the WT horses ($P = .03$). There was no difference in maximum heart rate, tidal volume, minute ventilation, respiratory frequency, lactate, and maximum speed during the maximal exercise tests pre- and post-conditioning. Average speed over the distance of the maximal exercise test increased by 17.4% ($P = .03$) in the WT group.

Research Abstract—for more information, contact the corresponding author

NOTES

4. Discussion

An 18-day conditioning protocol using a WT with high water level does improve the fitness and endurance of Thoroughbred 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.

How to Treat Endurance Sport Horses with Colic at Competitions

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1. Introduction

Endurance riding is an international, long-distance equestrian sport that in North America has been overseen by the American Endurance Riding Conference (AERC) since 1972. The Fédération Equestre Internationale (FEI) has been regulating international events since 1982. Since then, the number of entries in endurance events worldwide has increased more than four-fold and between 2007 and 2015 the number of endurance events has nearly doubled (FEI Endurance Report, 2016).¹ Endurance events (ranging from 50 to 100 miles, or 80 to 160 km in total distance) are split into successive phases of approximately 15 to 20 miles. At the end of each phase, horses are stopped for a veterinary inspection. Heart rate, hydration status, presence of gut sounds, and gait are the primary criteria evaluated at the veterinary check to determine whether the horse is fit to continue. Any horse deemed unfit to continue (due to lameness or excessive fatigue, for example) is immediately withdrawn from the event.

Lameness, dehydration, and metabolic disorders are the main causes of elimination in 160-km events.²⁻⁴ Elimination rates in endurance events vary from one geographical area to another.³ For ex-

ample, eliminations for metabolic disorders occur more frequently in hot and humid areas. However, lameness remains the most common cause of elimination in all countries.⁴ A recent study of 30,741 horse starts in FEI endurance events found that the mean elimination rate was 49%, primarily due to lameness (30%) and metabolic reasons (9%).⁴ AERC records show that the completion rate for 50- and 100-mile events in the United States between 1996 and 2016 has been 84% to 87%. Similar to what occurs on a global level, the main causes for elimination in the United States are lameness and metabolic disturbances.⁵

A significant number of eliminated horses (~12%) require emergency medical treatment,⁶ and early detection and early institution of appropriate therapies are key to successful outcome. The two main disease categories that require emergency medical treatment are exertional rhabdomyolysis and colic. Unfortunately, fatalities are recognized subsequent to prolonged endurance exercise, and between 2002 and 2014 the AERC reported 71 fatalities over 270,070 horse starts.⁷ This fatality rate of 0.26 per 1,000 starts is much lower than fatality rates reported for other equine sports; however, reducing fatality rates where possible will help with improving equine welfare in the endurance sport. Colic

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has been recognized as a common reason for elimination from equine endurance competitions and the leading cause of mortality in this group of horses and of the fatalities reported between 2002 and 2013, 75% had signs of acute abdominal pain.⁷ The leading cause of colic in the endurance horse is ileus, followed by Salmonellosis and enteritis.⁸ Electrolyte derangements including hypocalcemia, dehydration and lack of intestinal perfusion, and other factors are likely contributors to development of ileus in endurance horses. Recent reports suggest treating veterinarians are unaware of the unique conditions surrounding colic in endurance horses at competitions. The goals of this report are to raise awareness of the unique aspects of treating colic in endurance horses at competitions and provide specific recommendations for management of colic in this group of horses. Here we outline recommendations for emergency treatment of endurance horses with colic with the objectives of improving outcomes in these horses through early recognition and early aggressive treatment.

2. Materials and Methods

Data from recently reported AERC case fatalities were reviewed. This included veterinary examination findings of the individual horses during and after competition and veterinary records from referral centers if the horse was transported for further care. These findings, in combination with what has been shown in previous studies of endurance horses, prompted the need to disseminate more information pertaining to colic in endurance horses to equine practitioners.

3. Results

1. Veterinary examination: Endurance horses with gastrointestinal upset may show severe signs of colic but often do not have a significantly elevated heart rate to match the signs of pain. Heart rates of 50 to 65 beats per minute are common in painful animals.
2. Nasogastric intubation: A nasogastric tube should be placed to determine whether there is reflux. It is not uncommon for there to be no reflux on initial examination; however, with ongoing disease gastric filling may develop later. A nasogastric tube should be left in place in horses that are transported.
3. Although examination per rectum is an important part of our gastrointestinal evaluation, it is not recommended to subject endurance horses with colic to this procedure on first evaluation. Arabian horses are at increased risk for rectal tears⁹ and the presence of dehydration may add additional risk. In fact, findings of examination per rectum are often predictable: findings are often unremarkable, or reveal the presence of dry manure and/or intestinal distention. If ul-

trasound is available abdominal ultrasound may provide useful information with regard to stomach size, small intestinal luminal size, and gastrointestinal motility.

4. Fluid resuscitation: Horses should be fluid resuscitated early and aggressively. Fluid resuscitation should be initiated immediately after veterinary or owner recognition of abnormalities during competition or during recovery. Abnormalities may include overt signs of colic, but may also include persistently elevated heart rate (>60 beats per minute more than 20 minutes after stopping the exercise) and anorexia. An average-sized endurance horse (450 kg) should be administered 20 L of balanced electrolyte solution intravenously within 1 hour. Horses that have evidence of gastrointestinal disease or are suspected to have gastrointestinal disease should not be administered intragastric fluids.
5. Restraint: If the horse is showing signs of discomfort, the horse should be calmed down using appropriate doses of sedatives including xylazine and detomidine. Butorphanol can be included with these drugs. Non-steroidal anti-inflammatory drugs should not be used at this stage because of the nephrotoxic properties of these drugs, in particular in horses that have gastrointestinal damage or are volume depleted.¹⁰
6. Monitoring: The following laboratory parameters are useful for decision making regarding further care: packed cell volume (PCV), total protein (TP), electrolytes (Na, K, Cl, Ca, Mg), lactate, creatine kinase, and creatinine.
7. Continued management: If the horse is considered to need further care based on clinical findings or disease processes diagnosed, options for referral should be investigated. If the horse needs to travel to a location more than 45 minutes away, the horse should receive another 20 L balanced electrolyte solution intravenously prior to transportation. At this time, the horse should be checked again for development of reflux or the nasogastric tube should be left in place. The horse should not be transported without a nasogastric tube in place. These horses may require administration of 60 to 90 L intravenous balanced electrolyte solution per 24 hours. Horses should receive nothing per os.
8. Common causes for colic in endurance horses are ileus and enteritis. In addition, large colon impactions and gastric ulcers have been identified as causes for colic. Although it is very uncommon to find surgical lesions in this group of horses, there are those that develop colonic displacements or small intestinal strangulating lesions.⁸ Ancillary diagnostics that may be helpful to distinguish between surgical and nonsurgical lesions include ab-

dominal ultrasound and peritoneal fluid analysis. Specifically, evaluation of peritoneal total protein and peritoneal lactate concentration compared with peripheral blood lactate can be helpful with this decision.

4. Discussion

AERC data and other studies suggest that ileus is a frequently made diagnosis in endurance horses that die as a result of acute abdominal disease. One previous study has shown that ileus and enteritis are the leading causes of colic in endurance horses at competitions.⁸ In reviewing AERC fatalities it was discovered that there was improvement possible with respect to treating and managing horses with colic at competitions. Specific aspects that were noticed that could result in reducing fatalities were administering sufficient fluids intravenously, placing a nasogastric tube, avoiding examinations per rectum, and taking extra care when considering abdominal surgery. Fielding and Dechant⁸ showed in their study that 14% of horses underwent exploratory laparotomy, and surgical findings in those horses included perforated gastric ulcer, left dorsal colon fecolith, right dorsal displacement of the large colon, duodenitis/proximal jejunitis and small intestinal ileus with associated midjejunal impaction. Four of the five horses survived.

In conclusion, the main cause of colic in competing endurance horses is nonstrangulating small intestinal obstruction, most commonly caused by enteritis and ileus, and abdominal surgery is rarely indicated in this group of horses. To increase survival in endurance horses treated for colic, veterinarians should provide early aggressive fluid therapy at the site of competition prior to transport and provide appropriate length of therapy prior to recommending euthanasia. The prognosis for endurance horses with colic is good, even if exploratory surgery is required.

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.

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Characterization of Bony Changes Localized to the Cervical Articular Processes in Horses

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A high prevalence and wide variety of abnormal osseous changes were found at the cervical articular processes. Characterization of normal vs abnormal articular process changes will improve diagnostic interpretation of these findings. Authors' addresses: Gail Holmes Equine Orthopaedic Research Center, Department of Clinical Sciences, College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523 (Haussler); and Department of Large Animal Clinical Sciences, Michigan State University, East Lansing, MI 48854 (Clayton); e-mail: Kevin.Haussler@ColoState.EDU. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

Neck pain and stiffness is a common clinical entity in performance horses. Unfortunately, osseous pathology of the cervical articular processes has been poorly described and the prevalence of various types of osteophytes and enthesophytes is unknown. The objective of the study was to characterize and establish the prevalence of bony changes of the cervical articular processes in a mixed population of horses (i.e., variable ages, sizes, breeds) to better capture the full spectrum of disease affecting the cervical articular processes.

2. Materials and Methods

The articular processes of the cervical and first three thoracic vertebrae (C2–T3) from 56 horses euthanized for reasons unrelated to neck pain were evaluated for the presence and severity of abnormal bony changes.

3. Results

Seventy-two percent of articular processes had osseous changes that were considered abnormal. The

prevalence of abnormal changes varied between the cranial vs caudal articular processes: osteophytes (31% vs 17%), joint capsule enthesophytes (11% vs 1%), flattened articular surfaces (9% vs 37%), and remodeling (1% vs 20%). Overall grades of severity included mild (28%), moderate (22%), and severe (5%).

4. Discussion

The clinical significance of the described lesions is unknown, but the findings are expected to enhance the reporting and clinical interpretation of articular process and periarticular changes noted on advanced diagnostic imaging of the equine cervical spine.

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Research Abstract—for more information, contact the corresponding author

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Radiographic and Conformational Changes in the Feet of Growing Foals: An Overview

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A better understanding of hoof development allows for better management and prevention of diseases of the foot, ultimately increasing the duration of athletic careers and improving standards of living. Changes in the height of the palmar processes are likely to be associated with incidence of such fractures in the foals. Authors' addresses: College of Veterinary Medicine (Faramarzi, Salinger); Graduate College of Biomedical Sciences (Dong), Western University of Health Sciences, Pomona, CA 91766; Kaneps Equine Sports Medicine and Surgery, Beverly, MA 01915 (Kaneps); and College of Veterinary Medicine and Biomedical Sciences, Colorado State University, Fort Collins, CO 80523 (Nout-Lomas); e-mail: bfaramarzi@westernu.edu. *Corresponding and presenting author. © 2017 AAEP.

1. Introduction

The juvenile foot grows rapidly with a radical change of shape, which reveals a unique developmental pattern that has not yet been fully studied. The goal of this study was to quantify external and internal anatomical characteristics of the foot throughout the first year of development.

2. Materials and Methods

Digital radiographs and photographs were taken bimonthly of the forefeet of nine Arabian foals, beginning at 2 weeks of age until 1 year. Sixty-eight linear and angular variables were measured using ImageJ software. Statistical analyses were performed using piecewise random coefficient model and $P < .05$ values were considered significant.

3. Results

Significant changes in several radiographic and conformational measurements including palmar processes height, joint angles, phalanges/sesamoid bones width/length, toe and heel angles, and sole/heel widths between months 4 and 8 were identified.

4. Discussion

Diagnosis of equine foot problems early in their course is crucial to the overall long-term quality of life as abnormal growth patterns can precede foot diseases and subsequent lameness. Our results suggest that physical transformation in the foals' distal limbs starts between 4 and 6 months of age. The changes in palmar process height might be associated with the high incidence of palmar process fractures in foals.

Research Abstract—for more information, contact the corresponding author

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The Anatomy of a Contract: A Discussion of the Most Vital Components of a Veterinary Employment Agreement

Ky Mortensen, JD, MBA

This presentation explains the function of the veterinary employment agreement, providing a detailed analysis of its primary components, including compensation and non-compete provisions along with practical guidance on how to weigh the cost/benefit analysis of a contract's enforceability. Author's address: 193 Coy Road, Weatherford, TX 76087; e-mail: ky.mortensen@inovapartners.com. © 2017 AAEP.

1. Introduction

Many veterinary practices utilize employment agreements to detail the understanding of the employment arrangement between employer and employee. Considering the importance of a contract and its function as a legal tool, the need to understand the agreement is paramount to the success of the relationship. Although it is best to appreciate the language of the agreement at the outset of an employer/employee relationship, it is never too late to revisit the agreement and discuss its contents so that all parties are fully aware of the level of protection the contract affords as well as their own contractual obligations. Whether you are a new graduate looking for guidance, an associate seeking to better understand your current employment agreement, or an employer seeking to protect your business through the use of an enforceable contract, the need for veterinarians to understand their contracts is vital to the growth of an individual's career and to the health of a practice. Equal in importance is the understanding that contracts, while be-

ing legally binding in their nature, are the product of human beings. As such, reactions to contractual issues can be met with an emotional response that can easily compound the problem. Of utmost importance in any contractual dispute is the need to consider the real harm, understand your position, and to make an informed decision based on reasonable expectations and open communication.

2. Why Do We Need a Contract?

Among the primary reasons to have an employment agreement, the first is to detail any complex methodology of employee compensation. Many practices choose to pay practitioners on a commission structure rather than strictly on a salary basis. This method of compensation incentivizes the associate to become a higher producer as their level of production is realized in their monthly paycheck. It further motivates the practitioner to effectively use his/her time on each case, to fully charge for their services, to avoid discounting, and to sell professional services rather than merely dispensing drugs. The complexity of a commission structured compen-

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sation, if not done correctly, can be confusing and is an area begging for a misunderstanding if not clearly defined and strictly adhered to through the use of an employment agreement.

Another important reason to have an employment agreement is to detail the parameters of any confidentiality, non-compete, and non-solicitation provisions that the employer wishes to have in place to protect their business and to avoid training their future competition. The non-compete can be a deterrent to a new employee if not understood correctly. It can be also be an exercise in vanity on behalf of the employer if not carefully evaluated for its purpose and drafted with specificity to ensure its greatest opportunity for enforceability.

If your compensation method is strictly a yearly salary with no bonuses or commission payments and you have no need for any confidentiality protection or a non-compete provision, you likely can cover the arrangement with a traditional job description and an agreed salary statement.

3. Compensation

Compensation is the method and amount of money that the employer is willing to provide in exchange for the professional contribution of the employee. Once negotiated, it is important that the understanding between the parties be specifically described within the contract. This is particularly important when a commission-based pay schedule is in use. Commissions can be a driver for success or a recipe for disaster and the first step in getting them right is to ensure that both parties are on the same page with regard to how the commissioned payments are accrued and distributed. Some practices follow a general percentage-based approach wherein the employee is simply paid an overall percentage of their gross production. Others may choose to pay on gross collected production, meaning the total amount of payments that were actually received in a given time period, for work that was generated by a specific practitioner. A more sophisticated approach is to pay on the gross profits of collected revenues wherein a specified percentage is assigned as the compensation percentage for the profit margin of each service provided and paid as the revenues are collected by the practice. And finally, an even more complex methodology is to pay on collected revenues, from a commissioned percentage of gross profits, that vary in percentage based on the type of service given or product dispensed, all of which is calculated in a tiered system whereby payments that are received in an earlier timeframe are paid out in their entirety and payments that take longer to collect are paid on a decreasing scale. This system may pay 100% of the earned commission for invoices collected in a timeframe up to 90 days for example, and then 75% or even 50% of the earned commission for invoices paid from 90 to 180 days after time of service. These systems tend to pay no commission at all on invoices that take longer

than 180 days to collect thereby incentivizing practitioners to collect at time of service when possible, and to avoid doing work for bad accounts. All of these methods can be evaluated by the employer for their usefulness in increasing productivity and their fairness for rewarding veterinarians for their contribution to the practice. They are shared here only as an example of how easily a simple paycheck can become a confusing maze when payday arrives. This illustrates how necessary it becomes that the exact methodology of determining a rate of compensation be understood and accurately described within the four corners of an employment contract, to avoid any misunderstanding.

Of greatest importance for purposes of our discussion is to first ensure that the practice is capable of calculating the compensation according to the agreed upon method, and secondly that the methodology of calculation is defensible in court. Many practices will rely on practice-management software to ensure that the calculations are correct; however, regardless of the system or method you choose, it must be carefully described in the contract and accurately applied each pay period to ensure that there are no misunderstandings or discrepancies in compensation. Any breakdown in this area can be devastating to the level of trust between employer and employee and can be the impetus of considerable legal and/or financial agony should a mistake arise.

4. Understanding Your Non-Compete and Non-Solicitation Clause

On its face, a non-compete in a veterinary contract can be an ugly sore that sticks out with its threatening language and its protective tone. New veterinarians are often concerned by its limiting provisions and without an understanding of what it really means, can become less than enthusiastic about a new position because of the unknown. Equally as problematic is a veterinarian signing the non-compete agreement, assuming the provision is unenforceable. Conversely, employers may find a level of comfort in a non-compete, but that comfort may be misleading when push comes to shove due to the employer's oversight of several key elements that must exist to make a non-compete enforceable. Those elements include the following:

Consideration: Whether or not something of value has been offered in exchange for the employee's willingness to agree to the terms of the non-compete provision. This is best accomplished by offering a signing bonus or something of reasonable value beyond simply offering the employee the job.

Duration: This is the time period during which the non-compete's restrictive covenants are to be in effect. This can range from a year up to even 5 years depending on the value of the employee and the potential threat they represent should they openly compete against their current employer.

Geographic distance: This is the distance (typically a radius) surrounding your practice that is to be “off limits” during the time of the non-compete. Again, depending on the type of practice, its setting, and the location of the core clientele, the geographic distance can range from a city block up to more than 100 miles.

Scope of activity: This is the type of activity (providing professional veterinary service) that is not to be permitted within the restricted geographic area throughout the duration of the non-compete. Typically you would want to restrict only the type of veterinary service that is offered at the current employer’s practice. Anything else would not be viewed as being competitive in nature.

Non-solicitation: Not to be confused with a non-solicitation agreement, the non-compete strictly prohibits the employee from competing against the employer within the described area for the time period agreed upon. Non-solicitation provisions protect the employer against open solicitation of the employer’s clients or other employees by the former employee after they have left employment.

5. What About Benefits, Days Off, and On Call?

The benefits that you provide to your employees may change over time. One year you may provide a 401k match, and the next year, due to financial constraints, you may be unable to continue the benefit. Employers are not required to offer retirement benefits; nor are they required to make matching contributions, profit sharing, or any other contribution.¹ However, when these benefits are guaranteed in an employment contract, the practices’ hands become tied and you are contractually bound to continue the benefit at the guaranteed level for the duration of the contract term. Absent an agreement that runs to the benefit of the employees (such as an employment agreement), employers are generally able to change employer-sponsored insurance policy at any time, with or without permission of employees.² When the benefits are left at the discretion of the employer, you are in a much better position to respond to changes in your practice’s financial situation from year to year. This is not to say that all changes will negatively affect the employee, but at least you have the leverage to adjust where necessary. An approach to addressing benefits within the contract, yet leaving the door open for making organizational changes where necessary can be to simply state that the employee will be able to take part in any benefits statutorily described under relevant laws and to participate in all of the

employer’s benefit plans, which are available to its employees from time to time.

Similarly, paid time off, company holidays, and on-call schedules should be part of your policies and guidelines and available in your company handbook, but not necessarily part of an individual employment agreement. There may be an argument, however, that if a benefit has continued to be provided over a long period of time, the benefit has become an “implied term of the contract” and therefore has full contractual status.³

6. Conclusion

Whether you currently have contractual employment agreements in use in your practice, or have considered utilizing them, it is important to understand their importance in veterinary medicine and the key components that make them most useful. Considering your payment structure and your need for a non-compete agreement will help you determine whether or not having employment contracts in place with your associates is necessary. Finally, if you do have the need for employment contracts, be sure to have them reviewed by legal counsel to make sure they are in keeping with state regulations and enforceable for the purpose that they are intended.

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No Legal Advice Intended: The contents of this abstract are intended to convey general information only and not to provide legal advice or opinions, nor is it intended as advertising or as solicitation for legal services. This abstract should not be construed as, and should not be relied upon for, legal advice in any particular circumstance or fact situation. An attorney should be contacted for advice on specific legal issues.

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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Not on My Turf!—A Guide to Understanding Non-Compete Agreements

Ky Mortensen, JD, MBA

Is your non-compete enforceable? Here is the truth about veterinary non-competes, geared to both employers and employees. A detailed analysis of the non-compete, non-solicitation, and confidentiality provisions of a veterinary employment agreement along with practical advice to help ensure that what you intend to protect truly is protected. Author's address: 193 Coy Road, Weatherford, TX 76087; e-mail: ky.mortensen@inovapartners.com. © 2017 AAEP.

1. Introduction

Whether you are an owner of a practice or a new or existing associate, a non-compete provision is typically the pinnacle of the employment agreement where questions tend to arise. Naturally, both parties want to position themselves for the greatest opportunity for future success and as a result, the non-compete can either be an unnecessary source of stress for the employee, or equally as damaging, carelessly shrugged off and ignored.

Here is the truth about veterinary non-competes, along with some helpful guidance in avoiding an unnecessary legal battle when a conflict does arise, testing the mettle of the language of your contract. Foremost on the mind of most employers and employees is the question, “is the non-compete enforceable?” As most lawyers will tell you... it depends. First it depends on the state where you practice. Not all states are friendly to non-competes, and certain professions (like the legal profession) do not allow them at all. California, Alabama, Colorado, Delaware, Massachusetts, and North Dakota will not uphold non-

compete clauses in employment contracts.¹ Be sure to check your state regulations regarding the use of non-competes for the practice of veterinary medicine before relying on contractual language to protect your practice from future competition.

Second, even if non-competes are allowed in your state, enforceability depends on a number of factors that make up the non-compete provision. The first factor is the “scope” of the non-compete. In short, the scope is meant to address what type of activity the non-compete prevents one from doing. Next is the duration in time of the non-compete and finally, the geographic restriction, meaning where it applies geographically in relation to the location of the practice and its clients.

Beyond an understanding of these core elements, we will also explore the significance of confidentiality provisions as they relate to a non-compete, as well as the difference between non-compete and non-solicitation agreements. And finally avenues will be discussed that may help avoid an unnecessary legal battle over a non-competes enforceability.

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2. The Framework of a Non-Compete

Consideration

A primary requirement for a valid non-compete is whether it is supported by adequate consideration. In other words, something of value must be exchanged in order for the employee to be bound by the non-compete. Again, state laws often weigh in on what is acceptable as consideration in a given jurisdiction. Traditionally, this is separate consideration than the traditional paycheck. This is consideration above and beyond being paid for performing your job. Put simply, when an employee agrees to a restrictive covenant, he or she has to get something in return. Depending on your jurisdiction, being offered employment, or being offered continued employment after employment has already begun is generally not enough to support a non-compete agreement.²

Examples of consideration could be a signing bonus of a reasonable amount, as well as the provision of confidential information that the employee is to receive as part of their employment. This information could be business plans, marketing plans, client lists, or other information that is not readily available to the public.

Once you have determined whether your state supports the enforcement of a non-compete and that there is adequate consideration, the non-compete is constructed utilizing the three key components of duration, geographic area, and scope of activity. Of utmost importance in determining the breadth of these components is making a determination that can be accepted as a reasonable restriction in each of these areas.

Reasonableness

When considering the duration, geographic distance, and scope of activity, a measure of reasonableness will be employed in any judicial evaluation of whether your non-compete should be upheld. What is reasonable to an employer may not be reasonable to an independent third party, such as a jury. Given that a court of law could be the final measuring stick of your non-compete agreement's enforceability, it is best practice to consider the standard of reasonableness at the outset rather than to cut too wide a swath and overreach the bounds of what one might consider an acceptable amount of restriction for the employee it was intended. The measure of reasonableness is not a "one size fits all." Reasonableness varies according to practice type, location, existing competition, and has wide variability given the level of threat that a current employee would pose should he/she openly compete against the practice at some stage in the future.

Duration

Duration is the amount of time that the non-compete is determined and agreed upon to be hon-

ored after the employee has left the employment of the employer. This can range widely depending on the type of practice, the area the practice is in, and the level of importance/dependence that the practice places on the practitioner. Some practices provide a simple 18-month non-compete for new associates, while a more senior member of the team may be subject to a 3-year non-compete. An owner in a practice may have a 5-year non-compete as part of their corporate bylaws or operating agreement.

Geographic Distance

The most important factor to bear in mind when determining the geographic reach of your non-compete is where you can reasonably defend your protectable interest. Many mileage radiuses get thrown around as industry norms, and while these might be helpful in giving you a general guideline, it is worth consideration to give some thought to your particular practice, the norms of your business, and what is routine in terms of the distance any ambulatory employees may travel to treat horses. At the same time, keeping in mind the population of animals in your area and running a parallel track of the percentage of those animals that are likely seen by your practice and the percentage that could be shared with other veterinary practices.

Another element of the distance factor is the placement of these area competitors in geographic relation to your practice and to the bulk of your clientele.

As you hone in on your key practice area and the distance from your practice where you reasonably can defend a protectable interest, it is important to realize that you are likely only going to get away with one defined radius of restricted activity. In other words, your principle location will need to be defined and your radius of protectable interest should extend only from that location. Some contracts will endeavor to claim that there is a radius of protected area extending for a given mileage distance from any location where the employee performed work for the employer. Taken literally, for an ambulatory equine practitioner this would mean that there is a separate radius surrounding every location of every horse farm, every back yard, and every horse show where that veterinarian did work. This could, in effect, extend the initial 50-mile radius up to a 300-mile radius simply by nature of the ambulatory practice that routinely travels far beyond the protected area of interest.

When challenged in court, it is unlikely that such a wide protected area will be recognized as reasonable and enforced as such.

This is not to say that multiple locations could not be enforced, but they would have to be significant locations that can be defended as a nexus of business in a given area. For example, if you have a hospital or clinic in the Midwest, and you routinely travel to a horse show region with a portion of your practice and generate a substantial amount of your total

gross revenues from that presence, then that presence could be significant enough to merit a protectable interest. Remember, those key words need to be used and defended in practice in order for the geographic distance to be reasonably recognized and upheld in court.

A small-animal practice in a large city may only have a non-compete geographic range of one city block, whereas an equine practice in a rural setting may have a 50-mile radius or more. This can be influenced not only by the location of your core customers, but also by the location of your biggest competitors. If your largest competitor is located 60 miles away and a large percentage of your customers are just beyond that range, then a larger radius may be acceptable. Again, it is driven by what is reasonable to one making a determination. Be assured, you can agree on many things on paper, but what is going to be upheld in the end may not always be what was agreed upon, rather, what is most reasonable to a court of law. In short, just because you can get an associate to agree to a 5-year, 100-mile non-compete does not necessarily mean it will be upheld.

Scope of Activity

This is the type of activity that you perform for the employer that is a threat to that employer should you stop performing that activity on behalf of the employer and start doing it in competition with the employer. To simply state the activity as the practice of veterinary medicine is likely overreaching the boundaries of a reasonable scope. A veterinarian that has practiced in an equine practice is not necessarily a threat to the business of that employer should they venture off and begin a small-animal practice. The broadest reach of an employer is to simply define the scope as being the type of services provided by the employee to the employer's patients rather than trying to specifically define equine medicine and what can be interpreted as equine veterinary medicine.

Public Interest

A final prong on a non-compete provisions enforceability, applicable in some states, is that of public interest. To be valid and enforceable, a non-compete agreement must not have a widespread detrimental effect on the public, particularly with respect to consumers.³ In other words, a practice cannot use the non-compete agreement as an attempt to secure a monopoly in a given geographic region. In establishing enforceability, the core principle is the notion that a party should not be subject to excessive and unreasonable restrictions that were "not designed to protect legitimate business interest, but rather to prevent the employee from working for competitors."³

Confidentiality

In the course of performing their duties, employees will have access to certain confidential and proprie-

tary information belonging to the employer. This is necessary for the employee to perform their job and is considered routine business practice in most clinical settings. To be considered confidential and proprietary the information must not be readily available to the general public and must relate to the employer's business and its clients such as business and marketing plans, patient lists, software, case histories, client contact information, x-ray films and personal and regular patient files, price lists, and methods of operation. This information is considered valuable and unique property of the Employer and would not be available to the employee otherwise. As such, the information should be protected both during the course of the employee's tenure with an organization and thereafter. As part of their employment agreement, many employees will be asked to also sign a confidentiality provision whereby the employee agrees that they will not utilize this information to interfere with the business of their employer.

Non-Solicitation

Although differing in its effect, the non-solicitation clause typically accompanies a non-compete in a veterinary employment agreement. Non-solicitation entails a promise on behalf of the employee that they will not openly solicit clients and/or other employees in an effort to interfere or take them away from the current employer. In other words, a non-compete states that an employee cannot work in a given area. Whereas a non-solicitation provides that the employee will not openly solicit the existing customers of an employer, or try and hire existing employees away from the employer. The two bring different approaches to protecting the legitimate interests of the practice. Together they provide a more complete level of protection to the employer.

Survivability

A well-drafted non-compete and non-solicitation agreement will include language providing for the survivability of a given provision. This means that even if a contract term should expire, the promise within the given provision does not. Often employment agreements are not timely renewed. Without survivability language within the contract, the promises could be interpreted as only being valid while the contract is in effect. Including survivability language to such provisions ensures that the covenants the contract entails will remain in force for as long as the employee is employed by the employer and that their effect will take place immediately upon termination.

3. But Now I Want to Quit... and Work for the Competition

It happens. Employees are hired, contracts are signed, shoved in a drawer, and the real work begins. Years later due to any number of circum-

stances, the employee makes the decision to leave the practice. It only makes sense that an employee, with years of service in a given area, with a given set of skills, and with the connections to a given clientele, would want to continue their career in that realm. Precisely the scenario that employers are trying to prevent, thus the non-compete in the first place. But what if there were a compromise, a way both parties could get what they want? In effect, the employer is not protecting their clients from an employee's professional service, it is the financial impact of that service, and the loss of business the employer may experience as a result that is cause for concern.

If the lines of communication are still open, it can be beneficial to work toward an agreed settlement wherein the employee can pay a given amount to be released from the non-compete. In many cases, the non-compete may not be released entirely, but it might be tailored or trimmed to allow the former employee to pursue new ventures without fully violating the original terms. For example, an employee may wish to work in a certain county or other geographic region, that although partially within the protected area, is not an open violation of the entire radius of activity. Other settlements may allow for a shorter timeframe, say 12 months, rather than 18.

Depending on the level of compromise the separation fee may vary. If the non-compete is bought out entirely, the fee will be higher. If only a small piece of the geographic pie is desired by the former employee, the fee may be smaller. Similarly, if the time period is completely forgiven, a higher fee vs a shortened time period that may merit a smaller buyout fee. A number of factors will influence your decision in negotiating the terms of a buy-out. Of greatest importance in achieving a successful outcome of any separation agreement is to work together amicably and keep the lines of communication open. When emotions began to impact the negotiations or the relationship deteriorates, the stage is quickly set for failure to reach a resolution and the potential pursuit of legal action to determine the enforceability of a non-compete.

One method of addressing a potential separation is to include buyout provisions as part of the initial contract. In this manner, the employee is well aware of what a separation buyout would cost if they chose to remain in the area and practice the same type of veterinary medicine. Although challenging, it is a measure of prevention that is unclouded by the emotional impact that is often accompanied by employment termination.

4. Addressing a Breach of Contract

When a breach of contract occurs, it is important to first explore your own actions and ensure that you as the employee or you as the employer have upheld your end of the bargain. The best way to lose a breach-of-contract case is to be the sole party in

breach of an enforceable provision. If you are the employer, make sure that you have complied with all provisions of the agreement first before taking any action against a former employee who is openly competing in violation of the non-compete.

In the absence of a settlement, when an employee does breach their non-compete the employer typically sends a letter known as a cease and desist, which advises the former employee to discontinue violating their non-compete. If this does not work, and communication lines are no longer open, a suit can be filed and the fight is now in the hands of the judicial system.

Potential Downfalls

It is best to first have your position evaluated by legal counsel to ensure that you are standing on good ground for a potential victory. Employers may make the mistake of assuming that their non-compete is enforceable, only to find that they have failed in one or more areas to adequately protect themselves through the language or the compliance with the details of their contract.

Areas of concern are as follows:

1. Employer breaches the contract
2. No legitimate interest to enforce
3. Agreement is for too long a time period
4. The so-called confidential information is something readily available to the public
5. Public health or safety would not be served.⁴

6. Alternative Resolutions

Should a dispute regarding a non-compete come to a deadlock, with neither party willing to negotiate further, legal action may seem inevitable. The court system may be a worthwhile option depending on the circumstances of the issue. As an alternative to litigation, and often as part of the litigation process, the conflict may find resolution through the use of mediation.

Mediation is a form of conflict resolution wherein the parties that cannot agree are brought together to explain their side and lobby for their interests before a neutral party. Mediation is not arbitration. Mediation is, as the name implies, a mediator or "middle person" who hears both sides of the argument and helps to reach a resolution. Arbitration, on the other hand, is a decision-making process wherein the arbitrator acts with authority in arriving at a conclusion that is legally binding.

A mediator's job is to help negotiate a settlement. It has been said that in a successful mediation, nobody feels like they've won. This is not to be confused as a loss on both sides, rather, the parties are presented with the potential fallacies in their arguments to the point that concessions on both sides are made so that a settlement can be reached.

7. Conclusion

Any non-compete provision can be grounds for confusion on the front end of the employment relation-

ship and a potential legal battle at the conclusion. Should you utilize a non-compete agreement in your practice or be met with one as an employee, be sure and have the contract reviewed by legal counsel well versed in the area of non-competes as they apply to your profession. As an employer, be sure you know your standards of reasonableness for your practice type and that you have the language of your contract meticulously reviewed on an annual basis to be sure that it is in keeping with changes in your state's legislation, and to be aware of any case law that has paved legal ground in your jurisdiction.

As an employee, have your employment agreement reviewed by legal counsel to ensure that you completely understand what you are signing. By understanding and acknowledging your obligations at the outset, you can more effectively navigate your career path according to the terms of your contract.

Acknowledgments

The contents of this abstract are intended to convey general information only and not to provide legal advice or opinions, nor is it intended as advertising

or as solicitation for legal services. This abstract should not be construed as, and should not be relied upon for, legal advice in any particular circumstance or fact situation. An attorney should be contacted for advice on specific legal issues.

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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What You Need to Know to Prevent Malpractice and Veterinary Practice Liability Claims in Your Practice

Nina Mouledous, DVM

Circumstances that result in insurance claims can be prevented through sound risk-management protocols in veterinary practice. Important gaps in coverage are a common oversight when veterinarians obtain and renew insurance policies. This lecture will give veterinarians tips on preventing complaints, claims, and securing appropriate coverage. Author's address: AVMA PLIT, PO Box 1629, Chicago, IL 60690-9850; e-mail: nina.mouledous@avmaplit.com. © 2017 AAEP.

1. Protecting You and Your Equine Practice Part 1

Introduction

This discussion will give equine practitioners tips on how to avoid both business and malpractice claims in their practices. In addition, information will be provided on the appropriate types of coverage needed for individual equine practices to assure broad protection against liability claims (general and professional), board complaints, and losses unique to veterinary medicine and practice owners (damage caused by patients, damage to biologicals, and mobile practices, and more).

Solution

A good place to start is by dividing the types of claims into professional (specific to veterinarians) and business (practice owners). First we will discuss professional liability. Any veterinarian with a license is at risk of having a malpractice claim or board complaint. Veterinary medicine remains one of the most highly regarded professions. Yet, there are many challenges still facing veterinary medi-

cine. At some point in their practice career, many veterinarians may face an allegation of malpractice or a license complaint. As veterinary medicine has advanced, the public expectations have increased. The emerging animal law courses taught at the many law schools in our country are resulting in the veterinary profession becoming more visible and more vulnerable to litigation. Therefore, veterinarians need to have appropriate insurance protection.

According to cited legal suits, malpractice can be defined as the failure of a professional person to use such reasonable skill and diligence as are ordinarily expected of careful, skilled, and trustworthy persons in his or her profession.¹ A veterinarian will be held to a performance level equal to that of others in his or her field. What other veterinarians would find reasonable is termed "Standard of Care." In other words, the standard of care is determined to be what a reasonable veterinarian would do in a particular situation.

The most common situations that prompt claims involve miscommunication, adverse events and unfortunate outcomes (without negligence), accidental

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loss or injury to animals boarding, collection procedures, economic loss, human injury, and negligence (mistakes and errors). This presentation will examine some of these common situations and discuss unique challenges specific to equine practice. How to communicate with clients when an unfortunate outcome occurs is a key component to decreasing complaints.

Malpractice (or professional liability) and license complaints can be avoided by practicing good medicine, using enhanced communication skills, maintaining complete medical records, and keeping people out of harm's way. Actual claim examples will illustrate how to prevent complaints.

Equine practice poses additional risks when compared with small animal practice because of the higher monetary value of patients, the special veterinarian-client-patient (V-C-P) relationship, the challenge of recordkeeping in the field, and the increased risks of human and patient injury because of the size and behavioral nature of these patients.

Malpractice insurance responds to allegations of negligence, but not every policy is the same. Understand how the rates are calculated (is it segmented by species or other criteria) and if your rate is affected when you file a claim. Look for features like a "consent to settle clause," which allows the veterinarian to control whether a claim will be settled instead of the insurance carrier. Know whether your policy is mobile or if it only applies at a listed physical location. Also understand the claims-handling process and how it is tailored for the veterinary profession. Ask about the experience of the attorneys provided by the insurance carrier in defending equine practitioners.

Practice Good Medicine

Veterinarians and their staff are human and medical errors can happen, which is why it is important to be protected with appropriate malpractice coverage. And even when veterinarians practice good-quality medicine and follow appropriate protocol, unfortunate outcomes can occur. Some are inherent risks and some may be alleged as mistakes by the client. Participating regularly in continuing educational opportunities and practicing on the cutting edge of medicine is essential to practicing good, sound medicine. There are new drugs, new procedures, new vaccines, new protocols, and new guidelines veterinarians continually need to be familiar with in practice. Veterinarians should refer patients if the expertise to perform a needed procedure is questionable. Veterinarians should always recommend what is in the best interest of the patient. A closed claim example of malpractice due to a poor medical decision will be discussed to illustrate how to prevent claims.

Enhanced Communication Skills

According to O'Connell and Bonvicini,² there is a proven relationship between poor communication

and claims. The most common causes of malpractice claims due to miscommunication are lack of consent; failure to inform the client of risks, prognosis or options; failure to inform clients of costs; failure to provide complete written and verbal aftercare instructions; and failure to listen or be available. Veterinarians should explain the risks vs benefits of a recommended procedure or drug and obtain owner consent.³ Using sound communication tools can help veterinarians handle upset clients, deliver bad news, and handle conflict. Communication in veterinary medicine is on different levels between the veterinarians, clients, and staff, which increase the risks of communication breakdowns in many places. In equine practice, communication problems arise because of the nature of the V-C-P relationship. Oftentimes the client relationship is with the handler or trainer rather than the owner, and obtaining consent can be challenging. The veterinarian is often faced with communicating the patient's medical situation with a third party who has care, custody, and control of the horse but does not pay the veterinary fees. Owner complaints arise when the owner receives an unknown veterinary bill. Medical history is often given by the trainer who may not have complete knowledge of the patient's medical background. Other miscommunication examples in equine practice that have resulted in claims are misunderstanding of outcomes, lack of consent by the owner, lack of followup, and language barriers. The importance and benefits of good communication will be reviewed with actual claim examples.

Disclosing Medical Errors

According to Bonvicini,⁴ research on the relationship between communication and malpractice risk has shown that the majority of the malpractice litigation in human medicine is related to poor communication between the patient and the physician. Although many veterinarians are adept at sharing bad news with their clients in a sensitive and empathic manner, when the bad news is an adverse outcome due to a medical error it requires additional tools, insight, and practice. Because of the fear of formal complaints and potential malpractice suits, veterinarians may be hesitant to disclose an unanticipated outcome or error. Tips on how to disclose medical errors to clients will be discussed.

Good Medical Records

According to Scoggins,⁵ if you are accused of malpractice, your medical records are your best defense. Complete and legible medical records are imperative for optimal protection when faced with a complaint. Medical records are an open component of your communication practices. Documentation should show sound professional judgment based on information available at that time. Check with your state practice act as to record requirements. A good rule to follow is that any veterinarian who reads your re-

records should be able to pick up where you left off with treatment of that patient.

Items that should be included in medical records are written consent forms, anesthesia logs, surgery reports, physical examination findings, diagnostics recommended and declined by the client, laboratory results, estimate sheets, and all communication including texts, e-mails, voice messages, and verbal conversations. Pictures and videos from smart phones can provide compelling information, especially for absentee clients. The quality of care will be judged on the records. The practice owns the records, including original radiographs. The client of the records is entitled to copies upon request within a reasonable time period. Equine practice, especially in the field, can be additionally challenging. Finding a suitable environment to write in the record and obtaining history and consent from absentee clients are a few of the challenges.

Keep Clients and Patients Safe

Human-injury claims are less common but can be the most costly and difficult to defend in court. Claimant attorneys may argue that a veterinarian is considered the expert in animal behavior and should be aware that animals can react suddenly when injured or scared. Unlike small-animal practice, patient restraint by clients is more acceptable in the equine industry, which opens the veterinarian to additional exposure for human-injury claims. Once the veterinary examination has begun, it is the veterinarian's responsibility to assure the safety of everyone in the immediate area. The risk of human and patient injuries is higher in equine practice because of the size of the patients, the "flight" nature of the patients, and inexperienced, non-employee handlers restraining patients. Practitioners should consider using chemical restraint whenever possible to reduce injuries to both patients and humans (employees and clients). Practicing sound medicine by making intelligent, safe restraint decisions prior to treatment will help reduce human and patient injuries.

Professional Extension (Animal Bailee)

Animal bailee covers damage to animals in your care, custody, and control resulting from an outside source and not related to a veterinary incident. Typically, this includes losses resulting from fire, theft, escape, flood, catastrophic weather, injuries in stalls, paddocks, pastures, in addition to many other perils not related to treatment. This is an important coverage for practice owners if their practice hospitalizes, boards and/or transports animals. A practice owner could be held accountable for injuries to or death of patients while in their care. Practice owners should check their policies for coverage of patient injuries not related to a veterinary incident. This is especially valuable to practice owners. Practitioners that are completely mobile and do not keep or transport patients in their care, custody, or control do not need this coverage.

An important exclusion often found in professional liability policies is that any loss of semen and embryos while in storage or transit is not covered. Veterinarians can ask their insurance provider about securing an endorsement to cover losses while in storage or transit by the insured veterinarian (not third party transit/UPS/FedEx).

Discussion

In summary, equine practice poses additional risks of claims when compared with small-animal practice. The higher monetary value of patients prompts clients to seek economic losses by filing a malpractice claim when faced with an adverse event. The special veterinarian-client-patient relationship, the challenging record keeping environment in the field, and the increased risks of human and patient injury all add to the potential exposures of equine practice. Know the perceived monetary value of your equine patients and secure policy limits in line with their value.

2. Protecting You and Your Equine Practice Part 2

Solution

Business Liability (Practice Liability)

Practice owners have additional liability exposures as well as malpractice. These risks include workers' compensation and employment practice liability claims if they have employees, property damage claims, general liability claims for nonemployee human injuries, and business interruption claims due to loss of income from property damage. There are several important endorsements often excluded from standard policies that are specific to the practice of veterinary medicine. Practice owners need to be aware of these endorsements or exclusions to assure they have appropriate coverage for their business.

Business Owner's Policy (Practice Owner's Package)

The scope of the veterinary industry is vast and growing in complexity every year. With a wide variety of business structures (from the solo mobile practitioner to the multi-location practice to referral centers), it necessitates a highly specialized insurance program. The most important factor when choosing an insurance program is choosing a program that fits the specific and individual business needs of that entity.

This discussion will touch on a variety of business insurance (property and casualty) claims that are unique to the veterinary industry and will demonstrate the subsequent effect on the business. There are three areas of focus: workers' compensation, employment practices liability, and property damage. Actual claim examples will be used to illustrate the real-dollar impact to a veterinary practice.

Workers' Compensation

Workers' compensation (WC) is a form of insurance providing wage replacement, medical benefits, reha-

bilitation, disability benefits, and survivor benefits to employees injured in the course of employment in exchange for a mandatory relinquishment of the employee's right to sue his or her employer for the damage caused by possible negligence.⁶ Most employers choose a workers' compensation plan based on pricing, but not all plans are created equal. Practice owners should review the coverage limits and consider whether their practice has unique exposures such as volunteers or international travel. The practice owner should be knowledgeable about the provider's procedures to prevent fraudulent claims. Insurance carriers should also provide resources and strategies to help the employee return to work as soon as possible after an injury and reduce disability costs. According to *The Hartford*, return-to-work programs treat work as therapy to help the employee recover up to three times faster, restoring productivity of both the employee and your business.⁷ Key features a WC provider should offer are employers' liability limits of at least \$500,000 with an option for higher limits, coverage for volunteers working at your practice, and risk-management tools. Ask about training tools for the entire team to utilize to reduce WC claims through strong safety protocols and education. Also look for a provider that does not automatically subrogate against your clients when a patient injures an employee.

WC premiums will be the most expensive insurance premium for a business owner. A high-experience MOD (modification factor, based on the frequency and severity of the claims reported at an individual practice) will negatively affect a practice owner's premium. Good risk-management policies in place for employees will help prevent high MOD experience.

Employment Practices Liability

Employment Practices Liability (EPL) is an area that deals with wrongful termination, sexual harassment, discrimination, invasion of privacy, breach of contract, emotional distress, and wage and hour law violations. An EPL policy responds to these allegations and provides legal counsel for the policyholder. EPL claims can be reported to the Equal Employment Opportunities Commission (EEOC) by employees at no charge to them. An EPL claim can be very stressful and the duty to defend these allegations could put a practice without EPL insurance in financial jeopardy.

Pregnancy discrimination claims are the most common EPL claims filed by veterinarians. Veterinary practices are at greater risk of pregnancy discrimination claims because of the higher percentage of female employees working in the veterinary profession. It is important for practices to have policies and procedures for pregnant workers so both the employer and the employee have clear goals to accomplish a workable solution. The employee should consult with her physician to determine what tasks can be performed and what tasks should be avoided, and the employer should be updated as the

pregnancy advances.⁸ Actual claims will be discussed to highlight how to prevent an EPL claim.⁹

Property Insurance

A typical business owner's policy covers three major components: the building, the contents inside (medical equipment, computers, furniture, pharmaceuticals, etc.), and general (casualty) liability. For veterinary practices, the exposures can be different than other small businesses. As a practice owner, consider the liability of clients loading and unloading horses on your property, a loss of power compromising your perishable pharmaceuticals or short-circuiting your x-ray unit. A fire could damage the contents of your building, including expensive medical equipment and patient files. If a staff member runs an errand on behalf of the practice and is involved in a car accident, the practice owner and the practice could be liable. If a horse kicks an ultrasound machine and damages it beyond repair, does the business insurance policy cover this type of loss? Practice owners should check the business owner's policy for key features that will protect the business from these real-life scenarios. Important endorsements to look for are: mobile equipment coverage (in transit and replacement value of equipment, not actual cash value), business interruption coverage, equipment damage from patients, mobile loss of income, and extra expense endorsement (protects mobile equipment and the business income if the practice vehicle is out of service due to a covered loss), temperature change (spoilage) losses of perishables, hired/non owned auto (protects the business if an employee driver is involved in an accident during a work related errand), and adequate limits to cover potential losses. These features may not be found in a standard business policy. Veterinary claim examples will be discussed such as spoilage of biologicals, animal damage to equipment, business interruption, and accidents related to hired/non-owned automobile coverage that will illustrate how to best protect against these claims.¹⁰

Discussion

Brokers and carriers should provide risk-management tools and training for their clients. These are provided as a way for insureds to educate themselves on current trends, safety procedures, and loss prevention. Most insurance programs provide client access to specified websites to help practitioners create a tailored risk management program. Resources found on these websites include employee training modules, articles on current safety trends, pre-loss prevention support, hazard identification tips, safety policies and procedures, and webinars. Physical resources are also available such as books, posters, or pamphlets to suit practice owners' specific needs. Using risk-management tools will help reduce claim frequency and severity. This translates to a safer work environment and overall lower policy premiums.

Acknowledgments*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 AVMA PLIT and employed as a Trust Veterinarian. The information provided in this paper has been obtained from data and products offered through the AVMA PLIT-sponsored Program.

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Current Horse Owner Petition for Telemedical Assessment of Equine Lameness

G. Robert Grisel, DVM

The familiarity and extensive use associated with smart devices among today's equestrians has generated a demand for telecommunication services relating to the veterinary evaluation of lame horses. Appropriately, the modern equine sports practitioner needs to establish a professional, ethical, and effective way of administering to this demand. Author's address: The Atlanta Equine Clinic, 1665 Ward Road, Hoschton, GA 30548; e-mail: bobgrisel@atlantaequine.com. © 2017 AAEP.

1. Introduction

Performing a search for the key words "lame horse" on a popular video Web site^a currently yields approximately 140,000 results. A minority of the footage comprises instructional videos intended to demonstrate general signs of lameness or highlight specific gait deficits. These are posted by professionals and non-professionals alike and are intended for anyone who might be curious. The vast majority of clips, however, are posted by horse owners who are summoning advice with regard to a possible reason for their horse's current performance issue(s). These posts are directed at anyone who is willing to provide feedback, irrespective of training or experience with equine lameness.

Veterinary medicine (not unlike other forms of medicine) has historically lagged behind the technology curve, particularly with regard to client communication. This is due to a number of factors not excluding ongoing professional and ethical concerns. Notwithstanding, a significant number of horse owners are seeking professional guidance in a different form than that currently available; one that does not require the time and expense associated

with a typical veterinary visit and hands-on performance evaluation.

The purpose of this prospective investigation was to identify the demographic profiles and current level of interest with respect to veterinary telemedical video correspondence within the performance horse industry.

2. Materials and Methods

An online survey request was sent to approximately 3200 horse owners and trainers via email. The study population was procured from the practice database and comprised regular clients, former clients, and non-client horse owners, the majority of whom resided in the southeastern United States. Survey forms were provided and submitted through an online survey service^b. Questions were intended to establish the following with regard to each participant (Fig. 1):

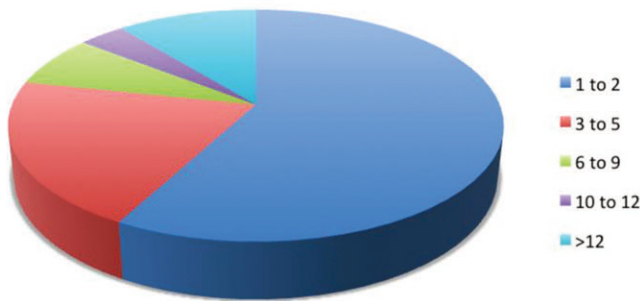
- Basic demographic profile with respect to equine lameness
- Current extent of video acquisition of lame horses

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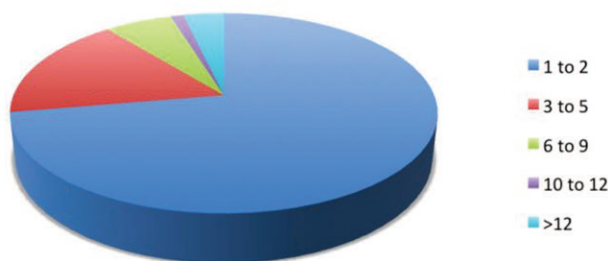
Type of Inquiry	Survey Question	Possible Responses						
Participant Demographic Profile	How many horses are under your care? <i>Mean ≤4.0; SD~4.6</i>	0 to 2 horses (48)	3 to 5 horses (17)	6-9 horses (6)	10 to 12 horses (3)	> 12 horses (9)		
	Approximately how many horses under your care have been evaluated for lameness? <i>Mean ≤2.5; SD~3.0</i>	0 to 2 horses (60)	3 to 5 horses (14)	6-9 horses (5)	10 to 12 horses (1)	> 12 horses (3)		
	Approximately how much money do you spend on treating or managing lameness each year? <i>Mean ≤2775; SD~3173</i>	\$0 to \$1,000 (30)	\$1,000 to \$2,500 (25)	\$2,500 to \$5,000 (15)	\$5,000 to \$7,500 (7)	\$7,500 to \$10,000 (3)	> \$10,000 (3)	
Participant Video Acquisition	Have you ever acquired a video of a lame horse moving?	YES (63)	NO (20)					
	Approximately how many videos have you acquired? <i>Mean ≤6.4; SD~5.4</i>	0 to 2 videos (15)	3 to 5 videos (24)	6-9 videos (6)	10 to 12 videos (6)	> 12 videos (12)		
	Why did you acquire the video(s)?*	To determine if I could see the lameness (15)	I wanted to get a non-professional opinion of the lameness (6)	I wanted to get a professional opinion of the lameness (59)	Other (5)			
Participant Internet Utilization	Have you ever uploaded footage of a lame horse to the internet?	YES (21)	NO (62)					
	Approximately how many videos have you uploaded to the internet? <i>Mean ≤4.1; SD~4.1</i>	0 to 2 videos (9)	3 to 5 videos (8)	6-9 videos (2)	10 to 12 videos (0)	> 12 videos (2)		
	Why did you upload video footage to the internet?*	I wanted to get a non-professional opinion of the lameness (3)	I wanted to get a professional opinion of the lameness (16)	Other (5)				
Participant Request for Professional Review	Have you ever submitted video footage to your veterinarian for review?	YES (59)	NO (24)					
	Approximately how many videos have you submitted for professional review? <i>Mean ≤4.6; SD~4.1</i>	0 to 2 videos (19)	3 to 5 videos (27)	6-9 videos (6)	10 to 12 videos (1)	> 12 videos (6)		
	How did you submit the footage?*	Via hard mail (0)	Via email (38)	Via text messaging (29)	Uploaded to YouTube® (8)	Uploaded to Web-based storage (Dropbox®, Google Drive®, WhatsApp®, etc.) (12)		
	From what device(s) was the video footage submitted?*	From Smartphone (44)	From iPad or Tablet (13)	From computer (22)	From other source (1)			
	Were you ever charged for this service?	YES (18)	NO (41)					
	Were you satisfied with this service?	YES (51)	NO (1)	Neither satisfied nor dissatisfied (7)				
	Why did you submit footage instead of requesting on-site examination?*	To save time (19)	To save money (11)	Distance: professional was too far away (34)	It was easier than having the professional come to the barn (17)	The professional requested the footage (34)		
Equestrian Petition for Telemedical Service	Would you like your veterinarian to offer telemedical video review as a service?	YES (65)	NO (1)	Depends on Cost (17)				
	What would be your primary incentive(s) for using this service?*	To determine if my horse is lame (39)	To determine if my horse needs to be seen by a veterinarian (53)	For pre-appointment (preliminary) assessment (66)	For post-appointment (recheck) assessment (54)	To screen the soundness of a horse that I'm considering for purchase (48)	For evaluation of a non-lameness issue (skin reaction, eye trauma, wound, etc.) (42)	
	Would you be willing to pay for this service?	YES (81)	NO (2)					

Fig. 1. Telemedical survey questions.

A. Number of Horses per Participant



B. Number of Horses per Participant Evaluated for Lameness



C. Annual Lameness Expense per Participant

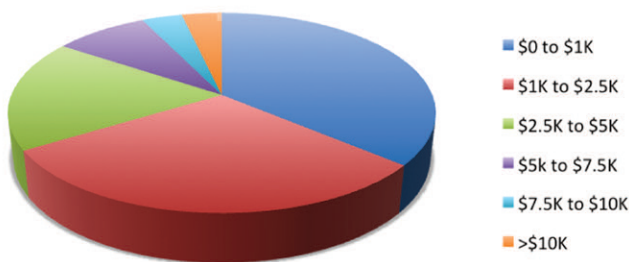


Fig. 2. Participant demographic profiles.

- Current utilization of the Internet to post video footage of lame horses
- Number of requests for professional review of video footage

- Petition for future veterinary telemedical services

Completed forms were evaluated and responses were reported as percentages of the whole within each of the aforementioned categories. Mean values and standard deviation were calculated when possible.

3. Results

Participant Demographics

A total of 83 responses were received. Of the equestrians participating in the survey, just over half (48 individuals, 57.8%) owned only one or two horses (Fig. 2A; mean ≤ 4.0 ; SD, ~ 4.6) and seventy (nearly 85%) spent less than \$5000 per year treating and/or managing lameness issues (Fig. 2C; mean ≤ 2775.0 ; SD, ~ 3173.3).

Participant Use of Video

Three quarters (63 or 75.9%) of the participants had previously acquired video footage of their horse(s) for lameness review (Fig. 3A). Of these, 59 (94%) acquired the footage with the intention of seeking veterinary counsel (Fig. 3B).

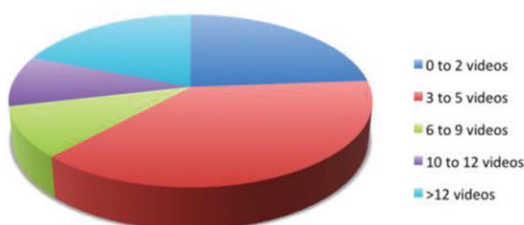
Participant Use of the Internet

One third (21 of the 63 equestrians) acquiring footage of their lame horses uploaded it to the Internet (Fig. 4A). Just over three quarters (76.2%) of these utilized Web-based services^c through which to submit footage for professional review. Fourteen percent of the participants were seeking non-professional advice (Fig. 4B).

Participant Request for Professional Counsel

By the time this survey was closed in 2017, more than 70% (71.1%) of all participants had already summoned professional evaluation via telemedical means. The majority of footage was sent via email (utilized by 64.4% of participants) and text messaging (utilized by 49.2% of participants). The smartphone, employed by three quarters (74.6%) of the participants, was the submission device of choice (Fig. 5C). Only one third (37.3%) of the contributors utilized their desktop or laptop computer(s).

A. Videos Acquired per Participant



B. Participant Impetus for Acquiring Footage

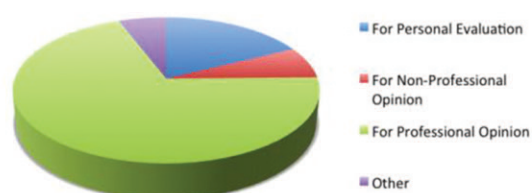


Fig. 3. Number of participants acquiring video footage.

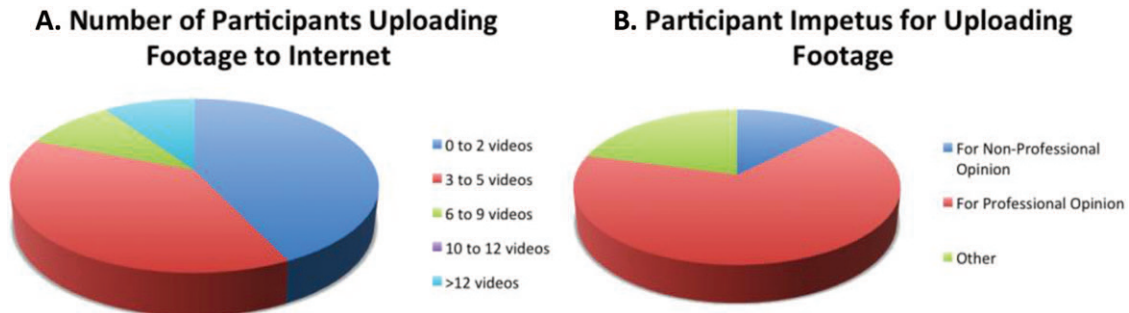


Fig. 4. Number of participants uploading video footage.

Excessive distance, considered by more than half (57.6%) of the participants, was a major catalyst in the decision to summon telemedical evaluation as opposed to scheduling an on-site appointment with the veterinarian (Fig. 5D). Almost one third (30.5%) of the horse owners procuring telemedical consultation were charged for the service. Overall, 86.4% of those contributing to this survey were satisfied with the review that they received.

Participant Petition for Telemedical Evaluation of Lameness

More than three quarters (78.3%) of equestrians contributing to this survey reported that they would prefer veterinarians to offer telemedical review of video footage as a service, citing a variety of reasons (Fig. 6). An additional 20.5% indicated that they would use such a service if it proved to be cost effective. Only two of the horse owners that completed the questionnaire (accounting for 2.4% of the

whole) reported that they would be unwilling to pay for veterinary medical consultation via telemedical means.

4. Discussion

The results of this survey support a demand for telemedical evaluation of video footage by equine veterinarians. Equestrians will likely continue to summon remote professional review, presumably at an increasing rate. Accordingly, many equine sports practitioners will be compelled to devise a long-term solution that will favor both the reputability and profitability of their practice. Several strategies relating to this form of evaluation have already been described^{1,2} although further qualification is needed.

Telemedical assessment services undoubtedly benefit the average horse owner by saving the time and money typically associated with regular on-site soundness evaluation(s). Given that most horse

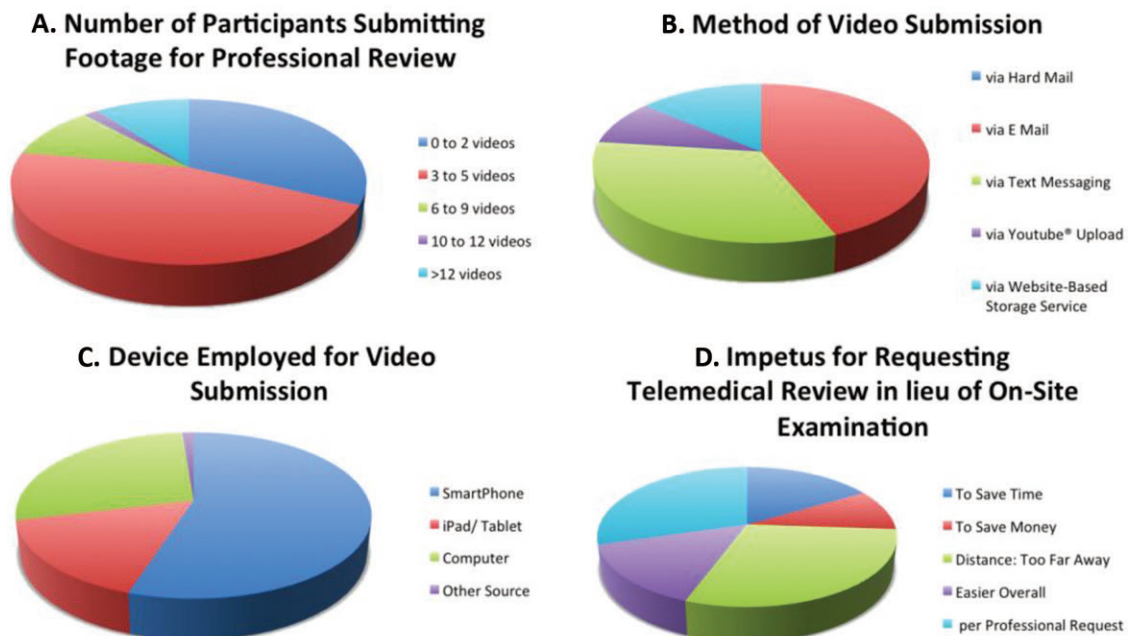


Fig. 5. Number of participants soliciting professional review.

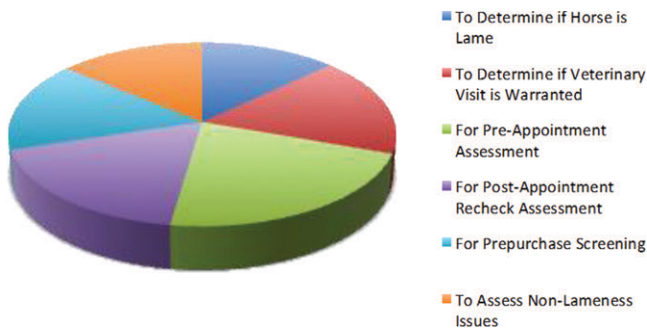


Fig. 6. Participant impetus for future telemedical review by veterinarians.

owners and trainers are not proficient at visually assessing equine lameness,³ timely advice from a veterinarian also accelerates the recognition of a problem, thereby hastening its diagnosis and treatment. This, in turn, improves the animal's prognosis for future performance.

Providing video review options also favors the veterinary professional by increasing the regularity and efficiency with which he/she can evaluate lame horses and communicate with clients. This in turn enhances the practitioner's overall accessibility and value from the client's perspective. Notwithstanding, this form of remote medical practice raises a number of issues that are worth considering:

- *Service validity.* To affix credibility and value to this service, veterinarians have to maintain ample proficiency with respect to their ability to visually assess movement of the lame horse.
- *Service profitability.* Almost 98% of equestrians that completed the survey would be willing to pay for telemedical review of video footage. Standardizing fee schedules for telemedical services is advantageous to the equine veterinary community.
- *Ethical considerations.* Many horse owners choose to solicit telemedical lameness assessment with the intention of replacing the more expensive and time-consuming on-site examination. In the author's opinion, it is important that the professional community regard telemedical review as a means of replacing a lack of (any) assessment as opposed to replacing direct hands-on evaluation, with the sole intention of inciting and/or supplementing the latter. Providing a diagnosis pursuant to video review alone is considered to be inappropriate and unethical practice.
- *Professional conduct.* Undoubtedly, veteri-

narians are already receiving video clips from horse owners outside of their practice's clientele pool and/or geographical boundaries. This poses concern with respect to unfair or non-licensed competition between veterinary practices. It should be emphasized that the primary goal of telemedical review is to precipitate an on-site meeting between the client and primary veterinarian at the appropriate time and under the proper circumstances.

- *Future installation of the modality.* Nowadays there are many ethical considerations affecting the practice of equine sports medicine. The appropriate use of telemedicine is quickly becoming one of them. Although this practice is relatively common and currently accepted in the fields of human and veterinary radiology, it has not yet established itself as an official method of visual lameness assessment. Nevertheless, the advent of smart devices make solicitation of telemedical lameness evaluation a natural alternative for the modern horse owner. Further investigation into the development of a professional, ethical, and effective way of administering to this demand is warranted.

Acknowledgments

The Author thanks the horse owners and trainers who took the time to complete the survey for the purpose of this investigation.

Declaration of Ethics

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

Conflict of Interest

Dr. Bob Grisel is the owner of dasWächter, LLC, which developed and is currently marketing Get-Sound™, a web-based app used to facilitate remote veterinary assessment of horses via smartphone dialogue.

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^aYouTube, LLC, San Bruno, CA 94066.

^bEmailMeForm, LLC, Redwood City, CA 94064.

^cDropbox, San Francisco, CA 94107, WhatsApp, Inc. Mountain View, CA 94041, Google, Mountain View, CA 94041.

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