EQUINE VETERINARY EDUCATION/AMERICAN EDITION VOLUME 33 NUMBER 11 NOVEMBER 2021

EQUINE VETERINARY EDUCATION

American Edition | November 2021

BEVA

The official journal of the American Association of Equine Practitioners, produced in partnership with BEVA.

IN THIS ISSUE:

Ethics: A matter of opinion?

Successful outcome after surgical correction of large colon atresia in a colt foal

Post fetal death development of endometrial cups in a Jenny donkey *(Equus asinus)*

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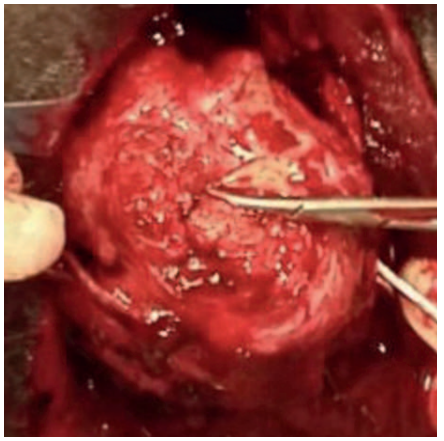

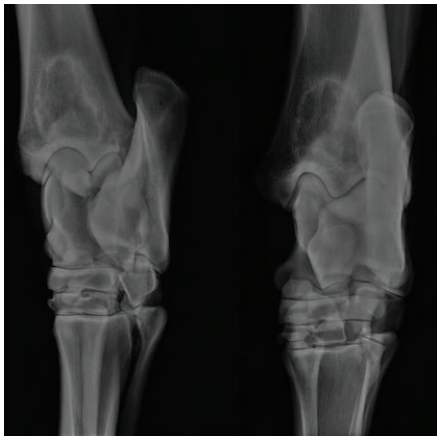

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Equine Veterinary Education is a refereed educational journal designed to keep the practicing veterinarian up to date with developments in equine medicine and surgery. Submitted case reports are accompanied by invited reviews of the subject (satellite articles) and clinical quizzes. Tutorial articles, both invited and submitted, provide in-depth coverage of issues in equine practice.

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Ethics: A matter of opinion?

By Juliea McCall, DVM

Dr. Juliea McCall

"In ethics, as in any other area, people's perceptions to a great extent reflect their training."
-Bernard Rollin[1]

The philosopher Bernard Rollin states that "detecting ethical questions is, in some ways, like detecting lameness." (Rollin, p.32) We intuitively know that something is amiss, but the ability to identify the problem requires training. Why then, are our responses as veterinarians to ethical dilemmas frequently described as impulsive or intuitive? Why do both veterinarians and clients commonly default to describing ethics as "a matter of opinion" when conflict arises?

Research demonstrates that most people do not reason when making moral judgments, but rely instead upon subconscious biases and emotion. The intuitive response of knowing something is wrong is essential—it prompts us to pause and reconsider. However, it is by moving beyond reconsideration to analysis of our initial reaction that we arrive at a sound final decision and a coherent plan for its implementation.

Whether discussing our decision with clients, refusing to provide a particular service or resisting a cultural norm at a practice, our position is strengthened by a cogent thought process. It's not that our gut response or instinct is unimportant; it is just that when we stop there, we deny ourselves a thorough inquiry and, in so doing, reduce our effectiveness. When others disagree with our final decision—particularly if it declines their request—they cannot dismiss a rational response with the same ease with which they dismiss a reactive response.

Rollin states that according to some estimates, veterinarians spend nearly one-third of their time attending to ethical issues. (Rollin, p.31) That thought alone may inspire us to reframe our approach to ethical considerations. He offers the following questions (Rollin, p.38) as a starting point to guide ethical inquiry:

1. Does the situation confronted require that judgments be made regarding good and bad or right and wrong?

2. Does the situation raise options that appear problematic (i.e., lying or concealing facts)?

3. Does the situation pit the welfare of humans against the welfare of animals?

4. Does a conflict exist between obligations to oneself and other obligations in the case?

5 Are veterinarians being asked to violate any principles that they hold (i.e., to cause no harm, to relieve suffering)?

6. Does something feel "not right" about a choice being contemplated?

Ambiguous situations in which there is no clear law to lean on are complex. There is a spectrum of response that can be considered rational, so equally valid defenses exist for differing responses. Examples include euthanasia, pre-purchase exams and the conflicts that arise as client versus patient interests on emergency calls.

The art of ethical reasoning lies in selecting which moral principles—the premises which we concede—to apply to the situation or the conflict being assessed. Examples of moral principles include choosing the greatest good for the greatest number of people or animals (utilitarianism); treating others as we wish to be treated ("the Golden Rule"); the idea that animals have their own lives as creatures and, thus, a moral status distinct from their legal status as property (intrinsic value); honesty (adherence to the veterinary oath); and truth (in its simplest form: the common agreement that lying is wrong).

Selecting principles that further an objective assessment of the situation rather than principles that support a presupposed position or a desired outcome, and questioning our motives every step of the way, constitutes solid ethical reasoning.

Practical ethical dilemmas often do not hinge upon assessing a situation, but upon standing for what is obviously right amidst a myriad of competing forces (client or employer pressures, practice culture, finances and competition). In these instances, having a clear process upon which to rely on while determining our actions is essential.

An example of the type of practical dilemma that a younger practitioner may face is pressure from a client or a practice to participate in insurance fraud, an activity that we all agree is both wrong and illegal. Applying Rollin's questions while considering their response may

continued on next page

AAEP ETHICAL PRACTICE
Every Day-Every Time

Dr. Juliea McCall practices equine medicine and chiropractic care in Geneseo, N.Y., and serves on the AAEP's Professional Conduct and Ethics Committee.

5 things to know about AAEP this month

1. Save $100 by registering for the 67th Annual Convention in Nashville by Nov. 30 at convention.aaep.org.
2. Recent graduates: Don't get shut out. Register for one of only 60 spots at the AAEP's New Practitioners Symposium CE event in February at aaep.org/meetings.
3. While awaiting the return of Virtual Wednesday Round Tables in spring 2022, view on-demand recordings of 2021 sessions and related resources at aaepanywhere.org.
4. Equine welfare initiatives around the world recently benefited from the disbursement of grants totaling $1,013,487 from The Foundation for the Horse.
5. If you'd like to become more involved with the AAEP, complete the Volunteer Interest Form accessible through aaep.org/dashboard.

AAEP-supported soring bill introduced in U.S. House of Representatives

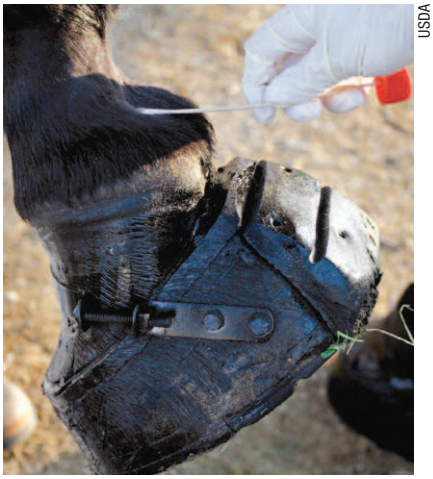
The AAEP commends representatives Steve Cohen (TN-09), Brian Fitzpatrick (PA-01), Jan Schakowsky (IL-09) and Vern Buchanan (FL-16) for introducing the Prevent All Soring Tactics (PAST) Act on October 1. The legislation (H.R. 5441) would protect Tennessee Walking Horses, Spotted Saddle horses and Racking horses by outlawing the abusive practice of soring, which is the intentional infliction of pain to create the exaggerated gait known as the "big lick" in the show ring.

At press time for this issue, the legislation has the support of 229 additional co-sponsors in the U.S. House of Representatives. In addition, companion legislation (S. 2295) introduced in the U.S. Senate on June 24 by Sen. Mike Crapo (R-ID) currently has 48 co-sponsors.

"For many years, the AAEP has championed legislation to end this cruel practice, and the recent reintroduction of this important bill to protect horses is vital," said Dr. Scott Hay, 2021 AAEP president. "We now will work for passage along with our more than 9,000 equine veterinarian and student members and the industry."

AAEP members in the U.S. are encouraged to contact their representative and senators and ask them to support the bill in their respective chamber and become a co-sponsor. Contact information is available at house.gov/representatives and senate.gov/senators.

The PAST Act is supported by the AAEP, AVMA and hundreds of other stakeholder groups and individuals,



USDA

including the American Horse Council, Humane Society of the United States, American Society for the Prevention of Cruelty to Animals and many state veterinary medical associations in the U.S.

Ethics, continued

help the veterinarian articulate their reasons for taking the stand that they need to take and, in so doing, defend the actions their conscience requires.

The process of answering the above questions and choosing which moral principles to invoke may help a veterinarian decline a client's request with authority or articulate the conflict as more than a matter of differing opinion when they discuss their views with an employer.

Examining our relationship to ethical reasoning is an opportunity for us to question the assumptions we hold about ideas of right versus wrong. It provides a method for us to consider our responses to ethical conflict with the same integrity we demonstrate when we detach ourselves from a presumptive diagnosis as the case data accumulates in an unanticipated direction.

Using rational considerations with which to assess our intuitive response to a moral conflict enables us to stand by our decisions with confidence and to weather the repercussions that unpopular but honest decisions sometimes invoke.

References::

AVMA PVME (Principles of Veterinary Medical Ethics) https://www.avma.org/resources-tools/avma-policies/principles-veterinary-medical-ethics-avma

"Veterinary and Animal Ethics," Bernard Rollin. In: Wilson, James F., Law and Ethics of the Veterinary Profession. Priority Press, Ltd: 2008 (1 p.31)

Colorado associate, University of Georgia professor emeritus to join AAEP board

Following a month-long vote by the membership that concluded Oct. 4, Drs. Jackie Christakos and P. O. Eric Mueller were elected to three-year terms on the AAEP board of directors. Each will be installed Dec. 7 during the AAEP's 67th Annual Convention in Nashville.

Dr. Jackie Christakos

Jackie Christakos, DVM

Dr. Christakos is an associate veterinarian at Littleton Equine Medical Center in Littleton, Colo.

Upon receiving her veterinary degree from Colorado State University in 2012, Dr. Christakos completed an internship at Littleton Equine Medical Center. She remained on staff as an assistant veterinarian to Dr. Terry Swanson before becoming a full-time associate in 2015. Her primary areas of focus are lameness/sports medicine and musculoskeletal ultrasound, but she also enjoys general practice/wellness care, emergency field work and acupuncture.

Dr. Christakos is an official FEI veterinarian for eventing and FEI permitted treating veterinarian. She has served on the board of the Colorado Veterinary Medical Association for the past four years, including as association president in 2021. Dr. Christakos is also active within the AAEP, where she currently serves on the Member Engagement and Professional Conduct and Ethics committees. She has also served as an instructor during the Extended Student Program at the annual convention from 2017-2019, session moderator during the AAEP's 2020 Virtual CE Summer Series and Table Topic moderator during the annual convention.

Dr. Eric Mueller

P. O. Eric Mueller, DVM, Ph.D., DACVS

Dr. Mueller is professor emeritus of surgery at the University of Georgia College of Veterinary Medicine, from which he retired in 2019. He currently owns and practices at Southeast Veterinary Consultants, LLC, providing lameness and surgical services and consultations on a limited basis.

After receiving his veterinary degree from Michigan State University in 1989, Dr. Mueller completed an internship, surgical residency and Ph.D. at the University of Georgia, where he started as an assistant professor of surgery in 1996 and became a professor in 2006. His clinical interests focused on lameness, equine gastrointestinal disease, and soft tissue and orthopedic surgery. Until his retirement in 2019, Dr. Mueller served in a variety of administrative roles, including residency program director, chief of large animal service, director of equine programs, director of continuing education and chief medical officer of the Large Animal Teaching Hospital.

Dr. Mueller has authored over 60 scientific publications and 20 veterinary book chapters. He is a frequent speaker at national and international scientific and continuing education meetings.

Dr. Mueller has contributed extensively to AAEP's educational offerings as a former member and chair of the Educational Programs Committee; program chair of several continuing education meetings; and presenter at the annual convention, at which he has co-anchored the popular Kester News Hour session since 2019.

Acquire practice profitability tips from new Practice Life podcast

With the cost of wages, fuel, drugs, supplies and miscellaneous practice expenses going up, there may never be a better time than right now for practice owners to genuinely understand the numbers behind their business.

During the October episode of the AAEP Practice Life podcast, entitled "Practice Profitability," Dr. Mike Pownall explores cost management and other key factors to staying ahead of inflationary pressures with two regular contributors to the business sessions at the AAEP Annual Convention: Dr. Bob Magnus, Wisconsin-based managing partner of Oculus Insights, LLP; and John Chalk, founder of Trinity Portfolio Advisors in Southlake, Texas.

In discussing means of coping with wage inflation at both the professional and lay staff level, Chalk suggests that practice owners confront their fear of raising prices. "In an inflationary environment," he said, "inflation means you can charge more than you could in prior periods. I think we shouldn't be afraid of that. I think we should embrace it. We should systematize it. Revenue, ultimately, is the fix."

Among the topics explored during the 38-minute episode are the key contributors to practice profitability, why associates should care about practice profitability, expense benchmarks for every dollar of revenue, suggestions for influencing the main profitability factors in a practice, hidden pockets of opportunity to manage costs, advice on wage inflation and determining when to finance or pay cash. Download or listen to the episode at podcast.aaep.org or on iTunes.

The AAEP Practice Life podcast is sponsored by Boehringer Ingelheim.

Practical solutions to everyday challenges: 2022 AAEP CE opportunities

Jan. 19–21, 2022

23RD ANNUAL RESORT SYMPOSIUM

Mauna Lani Resort • Kohala Coast, Hawai'i

Sponsored by Zoetis
Register at aaep.org/meetings

May 2–3, 2022

FOCUS on the Prepurchase Exam in the Sport Horse

Spy Coast Farm • Lexington, Ky.

Registration opens early 2022

Feb. 19–20, 2022

New Practitioners Symposium

University of Florida CVM • Gainesville, Fla.

Sponsored by CareCredit and Arthramid® Vet
Register at aaep.org/meetings

Nov. 18–22, 2022

68TH ANNUAL CONVENTION

Henry B. Gonzalez Convention Center
San Antonio, Texas

Registration opens summer 2022

For more information, visit aaep.org/meetings or contact the AAEP office at (859) 233-0147 or (800) 443-0177.

Recent grads: Acquire hands-on training at new labs-focused CE meeting

Diversify your skill set for the mutual benefit of your patients' health and your career trajectory by training in key areas at the AAEP's New Practitioners Symposium, Feb. 19–20, 2022, at the University of Florida.

Offering 10 CE credits and limited to just 60 participants who graduated between 2017–2021, the New Practitioners Symposium is a wet labs-focused event utilizing a "flipped classroom" model. Registrants will refresh their foundational knowledge through completion of relevant instructional material online at home prior to the event so that in-person time can be focused on experiential learning through skills application and analysis.

Attendees will rotate in groups of 20 through three 90-minute wet labs each afternoon. Each lab will have up to five instructors along with an adequate supply of equipment and horses to ensure plenty of hands-on training, instruction and skills development.

Feb. 19 Wet Labs
- Flash Colic Ultrasound
- Ultrasound of the Metacarpus/Metatarsus
- Radiology of the Skull (Sinus & Teeth)

Feb. 20 Wet Labs
- Podiatry: Films and Common Conditions
- Ophthalmology (Exams, Diagnostics)
- Ultrasound of the Stifle

The meeting will also incorporate lectures on pertinent medical and non-medical topics essential to successful practice; a business round table session during which attendees can discuss topics such as starting a practice, navigating parenthood in practice and more with subject matter experts; and social events to enjoy collegiality and expand professional friendships.

For more information or to register, visit aaep.org/meetings. Early registration is encouraged due to the attendance cap. The registration rate is $400; those who maintained an AAEP membership for all four years as a student receive a 50% discount. If you need assistance with registration, contact Kristin Walker at kwalker@aaep.org or (859) 233-0147.

Reconnect with colleagues in person at #AAEPNashville

Celebrate equine practice with horse doctors from around the world at the AAEP's 67th Annual Convention in Nashville, Tenn., Dec. 4–8. Enjoy the return of the full convention experience by reestablishing valued relationships with colleagues, classmates and vendors, many of whom you likely haven't seen since before the pandemic; acquiring practical solutions for everyday practice; unwinding at daily social events; and enjoying Nashville's vibrant nightlife.

You may still register online at the reduced rate of $675 through Nov. 30; after this date, the rate increases $100. AAEP will provide a full refund should you decide to cancel your registration. On-site registration at the Music City Center begins Dec. 3 at 3:00 p.m. At check-in, you'll receive the 2021 *Proceedings* book containing all the papers being presented at the meeting that otherwise is mailed to AAEP members in January.

If unable to join your colleagues in Nashville, you can take advantage of virtual registration and receive live access to 12 Table Topics and on-demand access to all education sessions held in the four main ballrooms. On-site attendees receive the virtual option at no additional cost. CE hours from on-demand sessions can be earned through March 31, 2022.

Register and view the complete educational program and schedule of social events at convention.aaep.org.

Be sure to follow the convention through email and social media. Check your inbox each evening for news, recaps and more in the Convention Daily; "like" the convention on Facebook at facebook.com/AAEPConvention; and join the discussion on Twitter and view photos on Instagram by following @AAEPHorseDocs and using the hashtag #AAEPNashville.

Enjoy two unforgettable nights

On Sunday, Dec. 5, country music hit-writers will share the stage with ultra-talented veterinarians for an evening of legendary storytelling benefiting The Foundation for the Horse. Headlining Storytelling Nashville Style will be Grammy-winning artist Rory Feek and his friends Wynn Varble and Brice Long, who have written some of Nashville's biggest hits.

The 2 ½-hour event starts at 8:00 p.m. Doors and cash bar open at 7:30 p.m. All seats are $75, which includes a complimentary beverage and gift to The Foundation. Tickets will be available on-site while supplies last. The Foundation thanks event sponsors Merck Animal Health, Boehringer Ingelheim, National Veterinary Associates and Zoetis.

Cap the convention social scene by gathering with colleagues, exhibitors and others for a night of music, dancing, food and more at the After Party at the world-famous Wildhorse Saloon. This free event on Tuesday, Dec. 7 will run from 6:30–10:30 p.m. and is a great way to unwind from a day or learning. Although the Wildhorse Saloon is within walking distance, shuttles will be provided from the Music City Center. The AAEP thanks Zoetis for its continued sponsorship of the After Party.

Share your research and knowledge at the 68th Annual Convention in San Antonio

Deadline to submit an educational paper is March 15, 2022, 3:00 p.m. ET

AAEP members and others are invited to submit papers for consideration for presentation during the AAEP's 68th Annual Convention in San Antonio, Texas, Nov. 18-22, 2022. Eligible for consideration are scientific papers, "how-to" papers, review papers, abstracts and The Business of Practice papers.

Submitting your paper

- All papers must be submitted by March 15, 2022, 3:00 p.m. ET at https://s3.goeshow.com/aaep/annual/2022/AAEP_paper_submission.cfm. The system will shut down after this time.
- Be sure to familiarize yourself with the submission process well in advance of the deadline. You can set up your profile with paper and author information in advance and then upload your paper when it is complete.
- Since the review process is blinded, make sure your paper does not include author or institution names.

A few key points

- Products and equipment must be identified by chemical or generic names or descriptions and footnoted.
- Due to the length and complexity of the process, all deadlines are strictly enforced.
- Submission of a paper represents a commitment to present this paper at the meeting if it is selected.
- Selected papers will be printed in the 2022 AAEP *Proceedings* and presented at the 2022 Annual Convention. The presenting author will receive complimentary registration and an honorarium.

Ethical Considerations

- 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 submitted paper or with companies that manufacture or sell competing products.
- If your presentation references the use of a compounded pharmaceutical, ensure that you are familiar with the FDA guidelines on the use of compounded pharmaceuticals and that the product you reference is in compliance.
- All AAEP papers submitted for presentation should cite levels of evidence-based medicine.

Types of papers accepted

All paper presentations are limited to 15 minutes plus 5 minutes for Q&A.

Scientific papers should be a minimum of 600 words. Special attention will be given by the Scientific Review & Editorial Committee to material with practical content or new information.

How-to papers should describe and explain a technique or procedure used in veterinary medicine or the equine industry. The technique should be relatively new or not widely understood or used in practice. There is no word limit for how-to papers.

Review papers should update the membership on a new subject or gather information that may be conflicting. Although a review paper does not necessarily contain original data, it is anticipated that the presenter will have considerable experience in the field.

Abstracts may be submitted by authors who intend to publish in a refereed journal. A full paper conforming to the AAEP guidelines to authors must also be submitted (for review purposes only) to allow the reviewers to assess the experimental design, materials and methods, statistical analyses, and results (with graphs, tables, charts, etc.) and to discuss the results as they pertain to interpretation and conclusions. Abstracts must be at least 250 words.

Journals differ in what they consider to be "prior publication"; some allow an author to submit an abstract up to 1,000 words, whereas other journals allow only 250. It is the author's responsibility to contact the respective journal to discuss their prior-publication criteria so that their accepted abbreviated abstract will not jeopardize their publication in the refereed journal.

The Business of Practice papers may cover any business management topic that can help the practitioner and their practice achieve more success and improve profitability. The theme for 2022 is "Increasing Profitability in Your Practice."

Need help submitting a paper?

As an aid to private practitioners, first-time authors or members seeking guidance with their submission, AAEP offers a mentorship program in which experienced presenters are available to provide advice and direction. However, mentors are not responsible for rewriting or selecting material.

Contact Carey Ross, scientific publications coordinator, at cross@aaep.org for a list of available mentors or with questions concerning the annual convention and educational paper submission.

The Foundation for the Horse awards over $1 million in support of equine welfare

The Foundation for the Horse has distributed $1,013,487 in grants for 34 programs and projects committed to The Foundation's mission of improving the welfare of horses.

Allocated funds are earmarked for disaster preparedness programs in Kentucky and West Africa; continued support of veterinary first responders in areas prone to floods and wildfires; essential skills workshops and convention programming for students; and seven equine research projects spearheaded by graduate students and/or residents.

The disbursement also includes support for five working equid welfare projects throughout Central America, the Caribbean, Africa and the United States. Scholarship support to help students and recent graduates offset the financial strain of veterinary school includes the inaugural Dr. Bill Rood Leadership Scholarship, an endowed scholarship established by friends, colleagues and clients of the retired Rood & Riddle Equine Hospital co-founder.

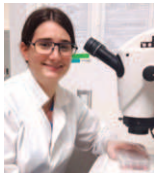
A complete list of 2021 grant recipients is available at https://tinyurl.com/w3j84543.

Foundation invests in clinical advances through support of seven emerging researchers

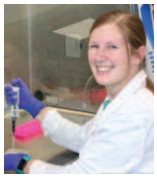
The Foundation for the Horse has awarded $131,717 for seven exceptional equine research projects being investigated by AAEP-member graduate students, residents or postdoctoral fellows. Since inception of the program in 2019, The Foundation has provided $326,398 in support of impactful equine research by up-and-coming investigators.

"We thank all donors who have supported The Foundation for the Horse and our growing equine research initiatives, especially the Thoroughbred Education and Research Foundation for their funding and collaborative support of Dr. Kooy's project," said Dr. Anthony Blikslager, Foundation Advisory Council Research Subcommittee chairman.

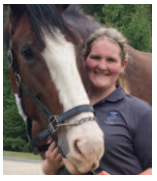
The supported researchers with project titles are presented below. Summaries of each project can be found at https://tinyurl.com/famftphs.



Elucidating host-pathogen interactions during equine placentitis
Dr. Machteld van Heule, University of California, Davis



Validation of chorionic girdle organoid culture as an invitro source of equine chorionic gonadotropin
Dr. Riley Thompson, Colorado State University



Investigation of genetic component of pergolide efficacy & adverse effects in horses undergoing treatment for pituitary pars intermedia dysfunction (PPID)
Dr. Lauren Hughes, University of Minnesota

Evaluation of persistence of chondrocytes or mesenchymal stromal cells after intra-articular injection – *Dr. Bethany Liebig, Colorado State University*

Equine placenta in lab: development of equine placental organoid
Dr. Margo Verstraete, University of California, Davis

An mRNA Vaccine to Immunize Foals Against *Rhodococcus equi*
Dr. Rebecca Legere, Texas A&M University

Direct and indirect effects of platelet rich plasma on neutrophil stimulation
Dr. Sarah Kooy, Auburn University

Dr. Kooy's project is supported by a gift from the Thoroughbred Education and Research Foundation, whose mission is to make racing safer through research and education. This is the second consecutive year that TERF has partnered with The Foundation for the Horse on important research with potential to impact the health and safety of Thoroughbred athletes.

The 2022 application window for this research grant program will open early next year. To learn more, visit https://tinyurl.com/ffthgsrrg.

MEMBERSHIP

Welcome to new AAEP members!

The following practitioners joined the AAEP between July 1–Sept. 30, 2021:

Rebecca Abanto, MVZ, Oakdale, CA
Christine Adreani, VMD, West Roxbury, MA
Lance Bassage, VMD, DACVS, Schenectady, NY
Kent Beattie, DVM, Saint John, NB, Canada
Kaylin Beatty, DVM, Bend, OR
Eden Bermingham, DVM, MS, DACVCP, Milton, DE
Avi Blake, DVM, Lawrence, KS
Bryce Blood, DVM, Cedar City, UT
Jennifer Bornkamp, DVM, Cherry Hill, NJ
Emily Brouckaert, DVM, Fowlerville, MI
Kristen Brown, DVM, Thousand Oaks, CA
Beth Byles, DVM, Arlington, VA
Lauren Canady, DVM, Doyline, LA
Carolyn Chisholm, DVM, Aubrey, TX
Katie Clark, DVM, Ravena, NY
Mariana Clarys, DVM, Nogales, AZ
Zoe Cocker, DVM, Salmon Arm, BC, Canada
Carlton Collett, DVM, Henryetta, OK
Ashley Cundiff, DVM, Penhook, VA
Benjamin DeYoung, DVM, Dixon, CA
Raechelle Dietsch, DVM, Earlysville, VA
Wynne DiGrassie, DVM, DACVT, Steeles Tavern, VA
Pouya Dini, DVM, Davis, CA
Cailin Drexler, DVM, Chamcook, NB, Canada
Jack Egan, DVM, Baldivis, WA, Australia
Scott Essex, DVM, Klamath Falls, OR
Jorge Falcon-Sillet, DVM, Lake Worth, FL
Melissa Fenn, DVM, Highlands Ranch, CO
Richard Fenton, DVM, Forsyth, GA
Lacey Floyd, DVM, Danville, PA
Jack Gillette, DVM, BVSc, Graham, WA
Megan Graham, BVetMed, Plymouth, MA
Megan Green, DVM, Bishop, GA
Cleet Griffin, DVM, DABVP, DAVDC-Eq, College Station, TX
Heather Grimm, DVM, Colstrip, MT
Justin Hayna, DVM, DACT, Downers Grove, IL
Frances Hinkle, DVM, DACVR, Raleigh, NC
Denisse Holden, DVM, Mesa, AZ
Hanna Hone, DVM, Carnduff, SK, Canada
Sara Howard, DVM, Prescott, AZ
Avi Iuchtman, DVM, Camon, Israel
Stephen Jenkins, DVM, Tillamook, OR
Mary Johnson, DVM, Odenville, AL
Nancy Johnson, DVM, Fort Blackmore, VA
Peter Kazakevicius, DVM, Ocala, FL
Heather Kehoe, DVM, Wausau, WI
Ann Kemper, DVM, Pullman, WA
Steven King, DVM, Yorktown, VA
Megan Knoell, DVM, Goshen, NY
Kelli Kolar, DVM, Great Falls, MT
Robert Kramer, DVM, Greenbank, WA
Amber Labelle, DVM, MS, DACVO, Gloucester, ON, Canada
Karen Laidley, DVM, Redmond, OR
Deanna Larsen, DVM, Airdrie, AB, Canada
Jo-Anne LeMieux, DVM, Oconomowoc, WI
Roxy Leyshon, DVM, Ocala, FL
Carol Lipinski, DVM, South Bend, IN
Anthony Loomis, DVM, Watchung, NJ
Vanessa Marcano, DVM, Gonzales, TX
Laura Lee Martin, DVM, Rose Bud, AR
Amy Middleton, VMD, Edmeston, NY
Wendy Miller, DVM, MS, DACVS, La Mesa, NM
Kendra Moulton, DVM, The Dalles, OR
Brittany Newsham, DVM, Brenham, TX
Steven Nicholson, DVM, Mira Road, NS, Canada
David Nicholson, DVM, Lewis, CO
Michelle Pothier, DVM, New Minas, NS, Canada
John Procter, DVM, Port Angeles, WA
Meghan Qualls, DVM, Millsap, TX
Caitlin Quinn, DVM, Washington, GA
Molly Rainforth, DVM, Lacombe, AB, Canada
Chris Randall, DVM, Ellsworth, MI
James Redmon, DVM, Prospect, KY
Tim Renn, DVM, Lucasville, OH
Jessica Reynolds, DVM, Ocala, FL
Rebecca Rifkin, DVM, Knoxville, TN
Caitlin Russell, DVM, Maryville, TN
Ricardo Sanchez Devora, DVM, Ronneby, Sweden
Meghan Sanders, DVM, Bolton, NC
Emily Sanford, DVM, Manly, NSW, Australia
Melissa Shelley, DVM, Haleiwa, HI
Courtney Sherman, DVM, Cowan, TN
Samantha Shields, DVM, Monon, IN
Reagan Simms Rodgers, DVM, Sinks Grove, WV
An Sleeckx, DVM, Canha, Setubal, Portugal
Kimberly Smart, DVM, Edgefield, SC
Willard Stoltzfus, VMD, Kinzers, PA
Michael Strobel, DVM, Northfield, MN
Tania Sundra, BSc, BVM, BVSc, Brigadoon, WA, Australia
Sarah Tabin, BSc, DVM, Centreville, MA
Luisa Taylor, DVM, Fort Collins, CO
Niels Tellerup, DVM, Herning, Denmark
Kathleen Theroux, DVM, MSc, Chesapeake, VA
Rachelle Thompson, DVM, Aiken, SC
Afton, Timmins, DVM, Ocala, FL
Joy Tomlinson, DVM, Brooktondale, NY
Ashley Vanderburgh-Oakley, DVM, Nobleton, ON, Canada
Marielle Vullers, DVM, Meijel, Limburg, Netherlands
Jenna Ward, DVM, Kennett Square, PA
Daniel Weldon, DVM, MS, Seale, AL
Luke Wells-Smith, DVM, Kilmore, VIC, Australia

INDUSTRY

AAEP Media Partner Profile: *EquiManagement*

EquiManagement is a proud AAEP Media Partner. *EquiManagement* is created for veterinarians, vet students and vet techs. It combines business, research and practitioner well-being content.

EquiManagement Business Solutions for Equine Practitioners

EquiManagement features a quarterly print magazine delivered with *EQUUS* to AAEP members, a frequently updated website, a veterinary equine health-related podcast (Disease Du Jour, brought to you by Merck Animal Health), and starting in 2021 The Business of Practice podcast (brought to you by Dechra). The magazine is also available as a downloadable PDF to our partners at NEAEP, BEVA, WEVA, NZEVA, AMMVEE, AVMA PLIT, ISELP, EPM Society and AAEVT. Sign up online for EquiManagement Update, our monthly business/vet wellness newsletter, and Research Reports newsletter with peer-reviewed article summaries.

Benefit: There's a market for pre-owned practice equipment

It's like eBay or Amazon for AAEP members, but without any buyer's premium or selling fees.

Whether you're in the early stages of your career and looking for pre-owned veterinary equipment to grow your practice, or you've recently upgraded and are looking to sell your used equipment, the AAEP's online Equipment Marketplace connects members on both sides of the commerce equation.

"I have converted thousands of dollars of underused equipment into cash through the AAEP's Equipment Marketplace," said Dr. Susan Moreland of Farmington, N.M.

Creating a listing is easy, and search capabilities allow you to narrow results to specific categories of equipment. From ultrasound machines and radiograph units to vet

boxes and dental tools, you'll find it all at aaep.org/dashboard/equipmentmarketplace.

If you have questions about the Equipment Marketplace, please contact Megan Gray, member concierge, at mgray@aaep.org.

Members in the News

Two members recognized by The Ohio State CVM

Dr. Janet Johnston

Dr. Craig Reinemeyer

AAEP members Drs. Janet Johnston and Craig Reinemeyer were among six recognized as distinguished alumni by The Ohio State University College of Veterinary Medicine on Oct. 7.

Dr. Johnston is a large animal internist and surgeon on the emergency service at the University of Pennsylvania's New Bolton Center. Among the earliest emergency and critical care specialists, Dr. Johnston has helped shape the specialty through her expertise and mentorship.

Dr. Reinemeyer is a prominent veterinary parasitologist who established East Tennessee Clinical Research, Inc. in 1997. The company carries out clinical drug testing to meet FDA standards in both large and companion animals and has helped bring a number of new products to market.

Auburn CVM honors a pair of members

AAEP members Dr. Mark Cheney and Dr. Timothy Stewart were among the Auburn University College of Veterinary Medicine alumni honored in mid-September during the college's 2021 Annual Conference and J.T. Vaughan Equine Conference.

Dr. Mark Cheney

Dr. Timothy Stewart

Dr. Cheney, a retired racetrack practitioner in Lexington, Ky., and member of the AAEP's Racing Committee in the late 1990s, was one of three recipients of the Wilford S. Bailey Award, the highest honor given to Auburn veterinary alumni. The award recognizes professional accomplishments in veterinary medicine, outstanding contributions to their community and the overall advancement of animal and human health.

Dr. Stewart, founding owner of Gulf Coast Equine Hospital in Summerdale, Ala., received the John Thomas Vaughan Equine Achievement Award, which recognizes leaders who help guide the equine industry to a better future. It is presented to an alumnus who exemplifies the Auburn spirit through leadership, dedication to and passion for one's profession, hard work that improves individual and community outcomes, and modesty in the impact they have had on others and the profession.

AAEP Educational Partner Profile: CareCredit

CareCredit, part of Synchrony's Health & Wellness platform, offers a veterinary financing solution that keeps equine veterinarians at the heart of care by helping clients manage the cost of care with simple, budget-friendly financing options with the CareCredit credit card. Clients can pay at the time of service, and the practice gets paid quickly.

CareCredit's all-digital, contactless financing experience supports all the ways equine care is provided. This custom link enables clients to learn about CareCredit, prequalify with no impact to their credit bureau score, apply and pay, all from their mobile device. The digital experience is even personalized to the enrolled practice.

Horse owners can use their CareCredit credit card to pay for everything from routine wellness services and medications to unexpected emergency care. Being financially prepared with an easy way to pay gives clients peace of mind while providing veterinarians greater certainty about cash flow and accounts receivable.

Over the past 25+ years, CareCredit has helped millions of clients pay for the veterinary care their animals need through every stage of life. The company is proud to be an AAEP Educational Partner and support initiatives that improve the health and welfare of horses as well as the financial health of equine veterinarians.

By bridging the gap between cost and care, CareCredit supports a healthy financial relationship between veterinarians and horse owners. Together, they can confidently move forward with the recommended care a horse needs, whenever it's needed.

To learn more about CareCredit, visit carecredit.com/equineinsights or call (844) 812-8111.

Demands of exercise are a stressor for the performance horse. Reactive oxygen species (ROS) such as free radicals are produced in the muscles during exercise. Heavy work can overwhelm the body's natural ability to deal with ROS resulting in oxidative stress which can damage muscle proteins, lipids, and DNA, release pro-inflammatory cytokines leading to muscle pain, and damage the mitochondrial membrane thus decreasing energy production.

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EQUINE VETERINARY EDUCATION
Equine vet. Educ. (2021) **33** (11) 562-563
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Highlights of recent clinically relevant papers

Effect of levothyroxine on racehorses

This study by Janice Kritchevsky and co-workers in the US sought to determine whether supra-physiologic doses of levothyroxine affect the velocities at which blood lactate was greater than 4 mmol/L (VLa4) and heart rate was over 150 (V_{150}) and 200 (V_{200}) beats per minute, respectively. A survey of post-race blood samples was also conducted to determine whether high thyroxine concentrations were common in racehorses.

Firstly, thyroxine concentrations were determined in 50 post-race blood samples taken at a single Standardbred meet. Secondly, six healthy Standardbred racehorses were trained to fitness and then randomised to one of three treatments: carrier, 0.1 mg/kg thyroxine or 0.25 mg/kg thyroxine for 2 weeks. Horses completed a standardised exercise treadmill test (SET) to fatigue on the last day of treatment. Serum free and total thyroxine and triiodothyronine were determined on the day of SET testing. Blood lactate and ECG data were collected during the SET at 6, 8, 10, 11, and 12 m/s and during recovery. The effect of treatment and SET on heart rate and blood lactate was examined.

The median thyroxine value in the post-race blood samples was 2.00 μg/dL (reference range 1.5–4.5 μg/dL) and 3/50 horses (6%) and 8/50 (16%) had concentrations above and below the reference range, respectively. Levothyroxine at 0.25 mg/kg resulted in higher heart rates during SET (199 ± 30, 223 ± 17 and 239 ± 9 beats/min at 6, 8 and 10 m/s, respectively) and recovery (144 ± 20 and 119 ± 15 at 5 and 15 min) as compared to placebo (176 ± 18, 203 ± 10 and 219 ± 6 beats/min at 6, 8 and 10 m/s and 126 ± 5, 102 ± 11 at 5–15 min, respectively). Three of six horses developed cardiac arrhythmias including atrial fibrillation.

The authors concluded that supra-physiologic thyroxine supplementation caused a decreased V_{200} during a standard exercise test and may result in cardiac arrhythmias.

SDMA in horses with dehydration

Acute dehydration caused by a variety of diseases in horses can lead to acute kidney injury; however, current renal biomarkers usually indicate renal damage late in the course of the disease. A novel biomarker would be helpful to diagnose renal disease earlier. This prospective cohort study by Hsiao-Chien Lo and co-workers in Germany explored the correlation between serum symmetric dimethylarginine (SDMA) and level of dehydration against traditional renal biomarkers, as well as its prognostic use as a biomarker of early renal injury.

Serum SDMA, creatinine and urea concentrations and renal function analysis were measured in 41 horses with dehydration at four time points until 48 h after admission. Horses were grouped according to their dehydration level into mildly, moderately, and severely dehydrated groups.

Serum SDMA concentrations at admission correlated with creatinine concentrations. Differences in SDMA concentrations at admission were detected among dehydration levels but not between survivors and non-survivors. Significant correlations of SDMA concentrations with other markers of renal function analysis and short-term outcome were not observed. Only one of the horses developed acute kidney injury, which made the evaluation of the predictive value of SDMA difficult.

These findings indicate that SDMA concentrations are correlated with creatinine concentrations in dehydrated horses. Use of SDMA as a prognostic biomarker warrants further research.

Survival in colitis cases

The objectives of this study by Sophie Sage and co-workers based in the US were to determine the impact of age on survival in horses with colitis and to elucidate whether a lower type-1/type-2 cytokine ratio or an exaggerated inflammatory state contribute to reduced survival in aged horses.

Part 1 included 124 adult horses with colitis. Patient signalment, select clinicopathological data, diagnoses, treatment, hospitalisation length, and invoice were compared between survivors (n = 101) and nonsurvivors (n = 23). Only age and plasma transfusion retained statistical significance in the final multivariate outcome model, with 8.5 times lower odds of survival in transfused horses (95% CI, 2.6–27.2%). Additionally, the likelihood of nonsurvival increased by 11.8% (95% CI, 4–20.2%) for every year the horse aged. Similarly, geriatric horses (≥20 years) were 15.2 times more likely to die than young adults (2–12 years), independent of financial investment, documented comorbidities, and duration of hospitalisation.

Part 2 included 29 adult horses with new diarrhoea onset while hospitalised. Select cytokine analyses were performed on serum collected from hospitalised horses within 1 h of diarrhoea onset (T0) and 6 h later. At T0, all recorded clinicopathological variables were comparable between geriatric and young-adult horses, suggesting a similar degree of systemic illness. The median concentration of type-2 cytokines interleukin-4 and interleukin-10, and type-1 cytokine interferon-γ did not differ between age groups. Inflammatory cytokines interleukin-6 and tumour necrosis factor-α were significantly higher in geriatric compared to young-adult horses at both sampling time points.

Outcome of colitis was less favourable in aging horses and patients receiving a plasma transfusion. Although an exaggerated inflammatory state, based on increased interleukin-6 and tumour necrosis factor-α concentrations, in geriatric horses may contribute to reduced survival, a lower type-1/type-2 cytokines ratio was not identified in the geriatric population in this study.

Enteric pathogens and colitis

This study by Jamie Kopper and co-workers in the US aimed to determine detection rates of potential enteric pathogens (PEP) or toxins (PEP-T) in faeces, blood, or both of horses with enteric disease and the effect of detecting multiple agents on outcome of horses with colitis.

Retrospective evaluation of PEP/PEP-T testing results was performed on 3753 faecal samples submitted to IDEXX Laboratories and 239 faecal and blood samples submitted to Michigan State University's Veterinary Diagnostic Laboratory (MSUVDL) to determine rates of detection of one or more

PEP/PEP-T. The impact of detecting multiple agents on outcome was assessed in 239 horses hospitalised for colitis.

One or more PEP/PEP-T was detected in 1175/3753 (31.3%) and 145/239 (60.7%) of samples submitted to IDEXX Laboratories and MSUVDL, respectively. In a hospitalised cohort, survival to discharge was lower (76%) in horses with one agent, compared to horses with either no (88%) or multiple (89%) agents. There was no difference in days of hospitalisation between horses with 0 (1–17), 1 (1–33), and >1 positive (1–20) result. There was no difference in cost of hospitalisation between horses with 0, 1, and >1 positive result.

Detection rates of PEP/PEP-T in horses with colitis vary with cohorts and tests performed. Detection of more than one PEP or PEP-T did not affect outcome.

Plasmatic procalcitonin in SIRS colic horses

This study by Irene Nocera and co-workers in Italy, Spain and Finland compared plasma procalcitonin (PCT) concentrations in healthy vs. systemic inflammatory response syndrome (SIRS) negative/positive colic horses over time, and evaluated PCT and SIRS score potential correlation, to verify the usefulness of PCT for the evaluation of SIRS severity.

Ninety-one horses were included; 43/91 were healthy, on physical examination, blood work and SIRS score (score = 0), while 48/91 were sick colic horses, classified as SIRS-negative (score <2) and positive (score ≥2). A 0–6 point-scale SIRS score was also calculated (assessing mucous membrane colour and blood lactate concentration). PCT was evaluated at admission, and at 24, 48, 72 and 96 h, using a commercial kit for equine species. PCT differences between healthy vs. colic horses, healthy vs. SIRS-negative or SIRS-positive colic horses, at all sampling times, and the correlation between the SIRS score at admission with the SIRS score was verified by the ANOVA test.

Statistically significant differences were detected between healthy vs. all colic horses and between healthy vs. SIRS-positive or negative horses at all sampling times. No correlation was observed between the SIRS score at admission and PCT values. PCT was statistically higher in colic horses compared to the healthy ones, suggesting a role as a biomarker for colic.

Intestinal leukocytes

The aim of this study by Guido Rocchigiani and co-workers in the UK and USA was to provide a reference range of leukocytes in the intestinal mucosal and submucosal propria of normal horses.

Intestinal tissues from 22 Thoroughbred racehorses with no clinical intestinal disease, which had been euthanised because of catastrophic musculoskeletal injuries were included in this study. Neutrophils, lymphocytes, eosinophils, macrophages, and plasma cells were counted in five random 17,600-μm^2 areas of villus lamina propria of the duodenum, jejunum, and ileum, and deep lamina propria of the duodenum, jejunum, ileum, right ventral colon, left ventral colon, left dorsal colon, right dorsal colon, and small colon. Other features investigated in the same intestinal segments included villus height and width (small intestine), presence of ciliated protozoa, number of Paneth cells, subcryptal leukocyte layers (number of leukocyte layers between the bottom of the crypts and the muscularis mucosae), and submucosal leukocytes.

Lymphocytes were the most numerous cells in all segments analysed, followed by plasma cells, eosinophils, macrophages, and neutrophils. Eosinophil numbers were significantly higher in both lamina propria and submucosa of the large intestine than in the small intestine. The duodenum had shorter and thinner villi than either jejunum or ileum. The data provided from this study will be useful for diagnosticians examining inflammatory processes in the intestinal tract of horses.

S. WRIGHT
EVE Editorial Office

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EQUINE VETERINARY EDUCATION
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Editorial

Climate change—What can veterinarians do?

Climate change is the biggest threat to human and animal health in the 21st century, and the COVID-19 pandemic has increased awareness of the interconnections between human, animal and planetary health. As the leaders of 196 countries prepare to meet at the United Nations Climate Change Conference (COP26) in Glasgow in November 2021, the stark realities of climate change are being experienced across the world, as heatwaves, storms, rising water levels and food shortages impact communities. Climate change is no longer something that we need to prepare for and tackle in the future – it is with us now, and the consequences are set to escalate and intensify within the next few years. Whilst the major targets to reduce greenhouse emissions (such as ending the use of coal, stopping deforestation and investing in renewable energy) require political action and commitment, individuals and businesses, including us all in the veterinary sector, can take action to live and work in a more sustainable way.

It has been estimated that if global health care was a country, it would be the fifth biggest carbon emitter in the world. Unfortunately, there are very little data available that quantify the environmental impact of veterinary practice. However, like human health care, veterinary care is environmentally intensive, and the impacts are complex compared to many other industries. The results of a survey published in this issue of Equine Veterinary Education indicate that most equine veterinary professionals and students in the United Kingdom are concerned about climate change and sustainability but are generally unsure about what effective action they can take. The survey results mirror those of the 2019 Royal College of Veterinary Surgeons (RCVS) Survey of the Profession, where 62% of respondents disagreed or strongly disagreed with the statement that 'the veterinary profession pays sufficient attention to its environmental footprint'. In addition, a 2019 British Veterinary Association 'Voice of the Veterinary Profession Survey' revealed that 89% of vets said that they would like to play a more active role in the UK sustainability agenda.

Climate change is an emergency. When faced with emergency, we take action. So, what action can the veterinary profession, veterinary practices and individual veterinarians take to have a positive impact on climate change? Even if it does not feel like it, we have influence in many different arenas—be it in our personal choices, professionally, or how we use our political voice.

There are several veterinary associations and organisations that are actively involved with researching sustainability issues relevant to veterinary clinical practice and who have produced resources to help us work out how to reduce our impact. Vet Sustain (https://vetsustain.org) is one such group in the UK that aims to equip veterinarians with the tools and training that they need to drive sustainability in veterinary practice. The 'Greener Veterinary Practice Checklist' produced by Vet Sustain is a shareable graphic designed to help veterinary workplaces operate in a more environmentally friendly way. The graphic includes four major areas for action that cover practising responsible resource use, being sustainable in your operation, using medicines responsibly and empowering the team. Each theme has a list of ways that these actions can be achieved. The British Equine Veterinary Association (BEVA) has also formed a working group who regularly publish tips and information relevant to equine veterinary practices; the information can be accessed on the BEVA website (https://www.beva.org.uk/Home/About-BEVA/BEVA-Sustainability/Tips-for-Practices).

Most veterinarians benefit from a relatively high income, and sometimes that translates into a relatively high carbon lifestyle. We should all consider how we can reduce our personal carbon footprint. We should also realise that any changes to our individual actions have a ripple effect, influencing those around us. As professionals, we must look at ways in which we can reduce the harm that we are causing the environment through changes in our day-to-day work. This is only achievable through a massive group effort, which has to include re-thinking our clinical practices and how we deliver services, in order to reduce impact on the climate. We also have a political voice. Veterinarians consistently score highly in opinion polls as trusted professionals to tell the truth. We should use our influence to advocate for change – at home, in our workplaces, in our communities and in wider society.

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Case Report

Atypical thymoma in a horse: Diagnostic approach and application of an alternative histological classification system

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Keywords: horse; thymoma; thoracic mass; neoplasia; thoracoscopy

Summary

A 24-year-old Warmblood gelding was presented with a 2-week history of left forelimb swelling, intermittent lameness, pyrexia and lethargy. Previous treatments for suspected cellulitis with bandaging, administration of nonsteroidal anti-inflammatory drugs and various antimicrobials showed no improvement. The gelding had a marked oedematous swelling of the entire left forelimb, which was larger proximally. In addition, mild sternal and pectoral oedema was evident. Distension of both jugular veins and subcutaneous facial vessels was visible.

The diagnostic work-up included blood chemistry, cytology of pleural effusion, ultrasonography, radiography and the visualisation and collection of a tissue sample by thoracoscopy.

Haematology showed signs of a nonspecific inflammatory response with a total leucocyte count within normal limits, an increased neutrophilic granulocyte count and a decreased number of lymphocytes. Serum amyloid A was increased.

Ultrasonography of the thorax revealed pleural effusion and a mass with heterogeneous echogenicity at the cranial aspect of the heart. Ultrasound-guided thoracocentesis showed a nonspecific pyogranulomatous exudate. During radiography, a well-circumscribed radiodense structure cranial to the heart was evident but no further isolated structures were visible.

During thoracoscopy, an encapsulated nodular mass was observed cranio-dorsally in the thorax (**Fig 1**). Under optical guidance, a biopsy was taken and a presumptive diagnosis of neoplasia was made. A therapeutic intervention was considered impossible because of its size and localisation. The owner elected euthanasia due to the overall poor prognosis, prior to the histological interpretation of biopsy samples.

Post-mortem examination revealed a fibrous mass (approximately 40 × 30 × 30 cm) in the mediastinum cranial to the heart extending to the cranial thoracic aperture. Histology and immunohistochemistry revealed neoplasia of thymic epithelial origin.

Various histological classification systems have been described to characterise thymic neoplasia. Currently, the 2004 WHO histological classification system derived from human medicine is used in veterinary medicine and implies the following categories: type A (spindle-shaped cells), type B1 to B3 (epithelioid cells with increasing atypia and decreasing infiltration of lymphocytes), type AB (spindle-shaped and epithelioid cells) and thymic carcinoma (epithelioid cells with prominent malignant features). Moran and Suster (2008) advocated a three-group system, which classifies thymic neoplasia into thymoma (comprising WHO categories A, AB, B1 and B2), atypical thymoma (comprising WHO category B3) and thymic carcinoma. The neoplasm in the present case clearly had malignant potential, even in the absence of lymph node or distant metastases. Regarding its histological appearance, the diagnosis 'atypical thymoma' seemed to be most appropriate. To the best of the authors' knowledge, the present case report includes the first application of the Moran and Suster classification of human thymomas to an equine case.

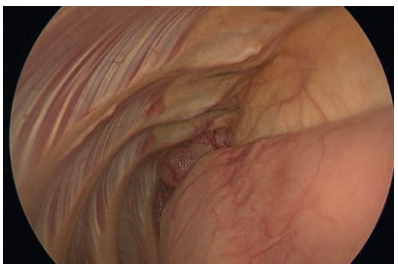

Fig 1: Thoracoscopic image: cranial view with Margo dorsalis of the lung (right ventral), ribs (left) mediastinum (right dorsal) and the thymic neoplasia (central).

Key points

- Thymic neoplasia is rare in horses.
- Symptoms of thoracic neoplasia are often shallow respiration and pectoral oedema due to pleural effusion. In addition, signs of vascular congestions and oedematous swelling of the forelimbs may be evident.
- In cases with a suspected pleural mass, the systematic examination includes ultrasonography and radiography of the thorax as well as thoracocentesis.
- Thoracoscopy is a useful technique to evaluate a mass and for collection of tissue specimens for histopathological examination.
- Equine thymomas show a high morphologic heterogeneity and diagnostic approach can be challenging. The classification systems by Moran and Suster can be applied to characterise them.

[1]Contributed equally.

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Case Report

Standing biceps brachii tenectomy to treat chronic bicipital tendinopathy associated with bursal fibrosis and humeral adhesions in a Quarter Horse gelding

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Keywords: horse; biceps brachii; tenectomy; standing surgery; shoulder lameness

Summary

A 12-year-old Quarter Horse gelding presented for chronic severe (4/5) lameness of the left forelimb with a significantly decreased cranial phase of the stride and a severe painful response to caudal limb retraction. Following localisation to the left shoulder region, intrabursal anaesthesia of the bicipital bursa resulted in a mild improvement in lameness. Ultrasonographic examination of the biceps brachii (BB) tendon revealed increased echogenicity of the lateral lobe at the level of the intertubercular sulcus.

Due to conservative therapy failure and a differential diagnosis of chronic BB tendinopathy, standing surgical exploration with potential biceps tenotomy was elected by the owner. The BB tendon was transected 5 cm proximal to the humeral tubercles and appeared markedly enlarged (**Fig 1**). Mature fibrous tissue adhesions were present connecting the BB tendon to the bicipital bursa and the cranial humerus and connecting the bursa to the cranial humerus. The bursa was fibrosed, and the synovial space appeared grossly reduced. The fibrous adhesions were transected. Approximately 10 cm of the BB tendon centred over the humeral tubercles was removed.

The post-operative diagnosis was chronic biceps tendinopathy with extensive fibrous adhesions to the cranial proximal humerus and secondary bursal fibrosis.

Following surgery, there was an immediate improvement in lameness with a considerable increase in the cranial phase of the stride. The rehabilitation programme consisted of 3 months of strict stall rest with a gradual increase in hand walking and daily passive range of motion of the left shoulder and elbow. At 3 months post-operatively, the horse began underwater treadmill exercise. At 6 months post-operatively, the gelding appeared sound at the trot, and at 8 months post-operatively, ridden exercise was introduced (**Fig 2**). At 12 months post-operatively, the horse returned to competitive barrel racing. The gelding remained sound, achieved preoperative performance and speed, and continued to compete successfully at this level with a 4-year follow-up.

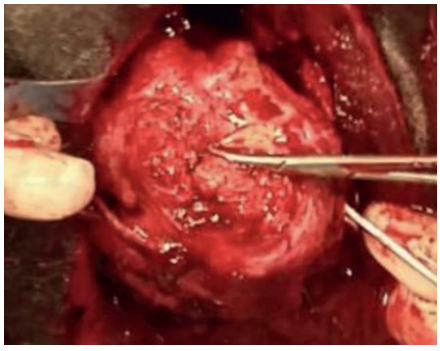

Fig 1: Reflection of the tendon of origin of the BB to allow visualisation of the grossly enlarged and fibrotic cross section.

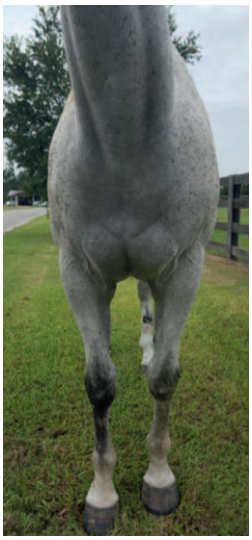

Fig 2: The horse 6 months post-operatively, exhibiting minimal shoulder muscle atrophy or asymmetry.

Key points

- In this case, tenectomy of the chronic unresponsive BB tendinopathy, and associated bursal fibrosis and humeral adhesions, was successful and resulted in a return to previous athletic performance without complications
- BB tenectomy may be indicated in similar cases of chronic tendinopathy, which are refractory to conservative management and when the integrity of the tendon is severely compromised.
- BB tenectomy may be performed successfully as a standing surgery under sedation and local analgesia.

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Case Report

Congenital stricture of the vestibulo-vaginal fold in a mare with normal karyotype

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Keywords: horse; vestibulo-vaginal defects; stricture; karyotyping

Summary

An 11-year-old showjumping Lusitano crossbred mare was presented at the University's Centre of Animal Reproduction at Vairão, for routine breeding soundness evaluation prior to entry into an artificial insemination programme. The mare was bright, alert and responsive, and had a good perineal conformation. Two clitoral samples were collected, screening for equine venereal diseases. No clitoral morphological abnormality was noted. Transrectal palpation and ultrasound examination of the reproductive tract (cervix, uterus and ovaries) was performed. No uterine fluid, uterine cysts or any other abnormality were observed. The cervix and uterus were tonic and ultrasound images were consistent with dioestrus, with one corpus luteum on each ovary. Collection of an endometrial biopsy was attempted, but an annular stenosis at the vestibulo-vaginal fold precluded access to the cranial vagina, cervix and uterus. The endometrial biopsy forceps were withdrawn from the vagina and digital palpation was performed. At the location of the vestibulo-vaginal fold, a tough, inextensible annular ring opening with a diameter of around 5 cm was detected, precluding the palpation of the cervix but confirming the existence of a cranial vaginal chamber. No painful reaction was elicited and no further dilation was observed, after digital exploration. Apart from this abnormal finding, no other pathology was detected. As a result of the vaginal anomaly, the collected clitoral samples were not submitted to the laboratory and further examinations were scheduled for 6 days later. The additional complementary examinations were reproductive tract ultrasound re-examination, vaginal endoscopy and blood collection for cytogenetic evaluation. The reproductive tract re-examination revealed a flaccid cervix, uterus and uterine horns and prominent oedema within the endometrial folds, consistent with oestrus. A 27 x 29 mm follicle and a 30 x 31 mm follicle were detected in the right and left ovary, respectively. Endoscopic visualisation of the vaginal canal and external cervical os allowed the visualisation of a distinct constriction of the vagina at the vestibulo-vaginal fold. Progressing the endoscope through the circumferential ring opening enabled the visualisation of the cranial vagina and external cervical os. Both had bright, pink mucosa with normal appearance. The external cervical os was positioned on the vaginal floor, consistent with oestrus. No fluid accumulation was observed on the vaginal floor. The mucosa of the cranial vestibulo-vaginal fold was also observed (**Fig 1**) and had a bright, pink mucosa with normal appearance. Cytogenetic evaluation revealed the presence of two X chromosomes. No mosaicism for numerical X aberrations was detected. In conclusion, the cytogenetic evaluation revealed a normal female karyotype (64,XX). The diagnosis was vestibulo-vaginal stricture. The owner was advised against breeding the mare and a consultation with a specialist in equine surgery was suggested to assess the possibility of reconstructive surgery to at least allow embryo collection.

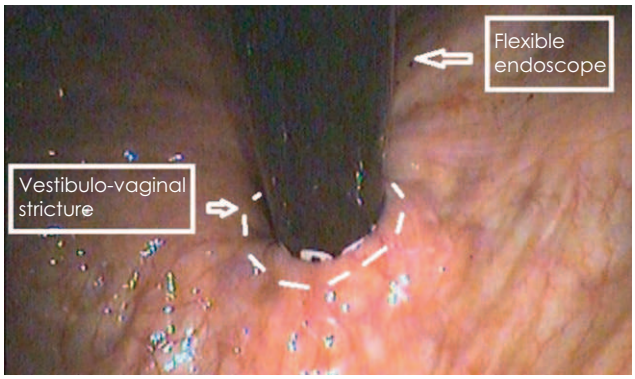

Fig 1: Endoscopic image of the vestibulo-vaginal fold (cranial aspect).

Key points

- Vestibulo-vaginal strictures are a rare congenital abnormality and can occur in mares with normal karyotype.
- Vestibulo-vaginal strictures in adult mares are usually not accompanied by obvious clinical signs.
- A careful prebreeding examination of every mare that enters a breeding programme is highly advisable.

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Case Report

Poor performance due to epiglottic retroversion in a Standardbred trotter

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Keywords: horse; epiglottis; retroversion; respiratory; overground endoscopy

Summary

A 3-year-old Standardbred trotting gelding presented to the Atlantic Veterinary College (AVC) for diagnostic work-up of poor performance and abnormal respiratory noise during exercise. Onset of clinical signs began approximately 6 months prior and diagnostics at that time, including physical examination, resting endoscopic upper airway examination and bloodwork, were unremarkable. The trainer elected to rest the gelding for 4 months; however, when exercise resumed, the noise persisted and the horse was referred to the AVC large animal hospital for further work-up.

Upon presentation, physical examination was within normal limits and no significant findings were identified on standing endoscopic examination of the upper respiratory tract. Treadmill endoscopy was used for dynamic evaluation of the upper respiratory tract, and a diagnosis of epiglottic retroversion was made. In this case, epiglottic retroversion first appeared as dorsal angulation of the epiglottis with visualisation of its oropharyngeal surface on inspiration. With continued exercise, the epiglottis began to retroflex further caudally, occluding the rima glottidis, before progressing to complete retroversion passing through the glottis beyond the arytenoid cartilages. Initially, the epiglottis returned to a normal position upon expiration but later in the examination it would remain retroflexed for several consecutive respirations. The frequency of retroversion increased with duration of exercise until it was occurring with almost every inspiration and a distinct, loud inspiratory noise coincided with the episodes of retroversion. During the immediate post-exercise recovery period, the severity and frequency of epiglottic retroversion decreased as the horse slowed its gait to a walk. No other respiratory abnormalities were noted during the treadmill endoscope examination. Due to the lack of available treatment options at the time and the poor prognosis for athletic function, the horse was humanely subjected to euthanasia and submitted for post-mortem examination (**Fig 1**).

This case represents the first reported results from a post-mortem examination of a horse with epiglottic retroversion. No significant findings were noted on gross examination of the head and neck. The brain and exiting cranial nerves, guttural pouches, epiglottis, larynx and laryngeal muscles were examined and deemed normal in appearance. Histologically, samples of the left and right facial, recurrent laryngeal, hypoglossal and glossopharyngeal nerves were all unremarkable. Additionally, no significant abnormalities were noted on sections of the brainstem, cranial nerve roots and both trigeminal nerves. Despite examination of the head and neck on post-mortem examination, no conclusive evidence was identified to support the postulated aetiologies for epiglottic retroversion that are currently found in the literature.

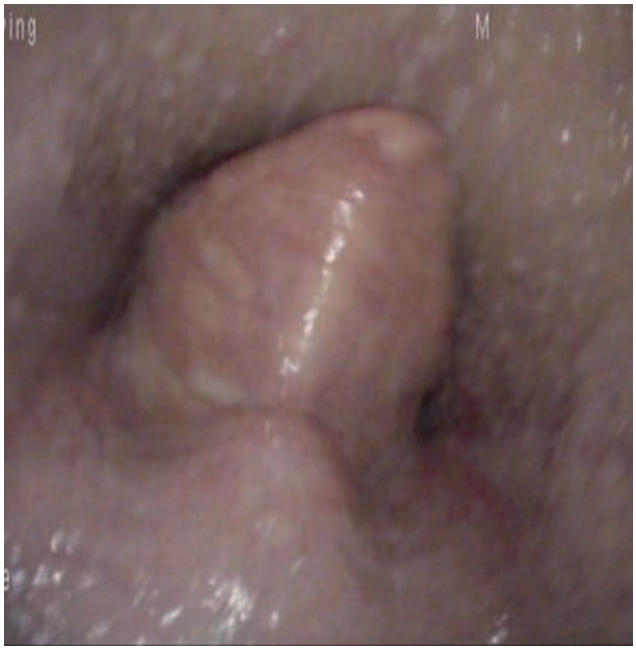

Fig 1: Epiglottic retroversion during high speed treadmill endoscopy. Note the epiglottis is retroflexed caudally to completely occlude the rima glottidis on inspiration.

Key points

- Epiglottic retroversion is a rare condition in horses that presents with nonspecific clinical signs including exercise intolerance and abnormal respiratory noise.
- The aetiology of this condition in horses is unknown and diagnosis requires dynamic examination of the upper airway during exercise.
- The prognosis for horses affected by epiglottic retroversion remains guarded although new treatment options have emerged which show potential for return to athletic function.

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Case Report

Surgical treatment of phimosis due to preputial stenosis in a Thoroughbred colt

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Keywords: horse; phimosis; preputial stenosis; congenital; surgical transection

Summary

A 6-month-old Thoroughbred colt presented with a 3-week history of discomfort and inability to protrude the penis during urination. This led to accumulation of urine within the prepuce and intermittent dribbling rather than normal release in a continuous stream. Previously, the colt had been observed to urinate normally. Clinical examination revealed an abnormally thick and fibrosed preputial orifice but otherwise normal penile anatomy. Under sedation the penis could be manually extruded, albeit against significant resistance, but retraction took several hours. With no evidence of trauma or a persistent penile frenulum, a tentative diagnosis of phimosis due to congenital preputial orifice stenosis was made. Exploratory surgery under general anaesthesia confirmed the presence of a constrictive ring of tissue reducing the diameter of the preputial orifice (**Fig 1**). At three sites where the constrictive annulus appeared thickest and most accessible, 2-cm stab incisions were made and the fibrous band identified, isolated and elevated (**Fig 2**) before transection with LigaSure Atlas™. This achieved satisfactory release, and skin and subcutaneous incisions were closed in two layers.

A sample of fibrous tissue was retained for histological examination. This revealed fibromuscular tissue composed mostly of skeletal muscle, with some regions showing mild intrafasicular fibrosis and myofibre atrophy. Although histology could not definitively confirm a congenital origin for the constrictive tissue ring, the clinical history indicated as such. With a single owner and no history of trauma it would suggest the preputial orifice stenosis had been present since birth. With growth the relationship between the penile tissues changes and at a critical point the stricture likely began to restrict protrusion, causing the restriction to become clinically relevant.

Post-operatively significant preputial oedema and swelling developed and initially the penis seemed to permanently slightly protrude from the prepuce. This resolved by 48 hours and CCTV observation confirmed the colt to be capable of normal penile extrusion and retraction during urination. Eleven months after surgery the colt continued to be able to extrude the penis and urinate normally. A slight excess of skin was present at the end of the prepuce but was only of minor cosmetic concern.

Fig 1: Penis extruded for surgery. The blue arrow points to the thickened ring of fibrous tissue causing stenosis at the level of the preputial orifice.

Fig 2: Thickened, fibrous, constrictive ring of tissue isolated and elevated prior to transection.

Key points

- Phimosis is an inability to protrude the penis past either the preputial ring or orifice.
- Congenital preputial orifice stenosis should be considered as a differential diagnosis in a young colt presenting with phimosis.
- Use of LigaSure Atlas™ to surgically transect and release the fibromuscular tissue ring constricting the preputial orifice is a quick, safe, effective and relatively easy treatment for phimosis due to preputial orifice stenosis in the colt.

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Case Report

Osteosarcoma in the femur of a horse

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Keywords: horse; osteosarcoma; femur; neoplasia; tumour; radiation

Summary

A 27-year-old Arabian pony gelding was presented for evaluation of weight loss, intermittent sheath oedema, persistent neutropenia and thrombocytopenia, and acute left hindlimb swelling and gait abnormality. Clinical findings included swelling, heat and sensitivity localised over the left greater trochanter, mild to moderate ventral and sheath oedema, a left hindlimb post-legged gait, and off-loading of weight from the left hindlimb at rest. Initially, neutropenia and thrombocytopenia were confirmed on complete blood count, but neutrophilia and thrombocytopenia persisted as the case progressed. Diagnostic imaging (radiography and percutaneous ultrasonography) of the left hindquarters revealed an aggressive, mixed proliferative and lytic bony lesion on the proximal left femur (**Fig 1**) as well as associated muscle fibre disruption and a soft tissue mass. A percutaneous core biopsy of the lesion led to the diagnosis of osteoblastic osteosarcoma on histopathology (**Fig 2**). Pain and inflammation associated with the lesion was medically managed in the hospital with minimal improvement. Additionally, palliative radiation was performed under general anaesthesia. Unfortunately, before a response to palliative radiation could be assessed, the patient was subjected to euthanasia due to development of acute neurologic signs.

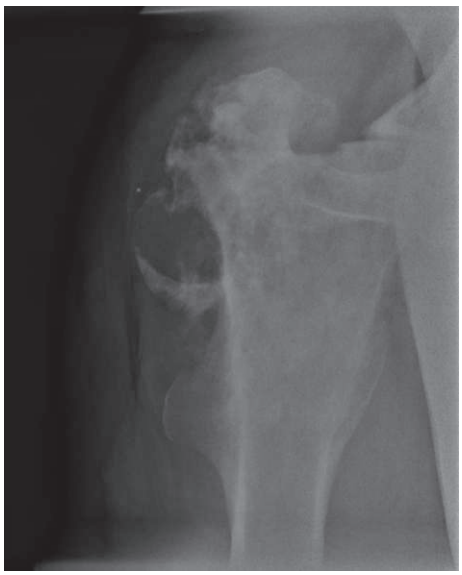

Fig. 1: Cranial-caudal view of the left femur shows an aggressive, mixed proliferative and lytic bony lesion over the left femoral greater trochanter and third trochanter.

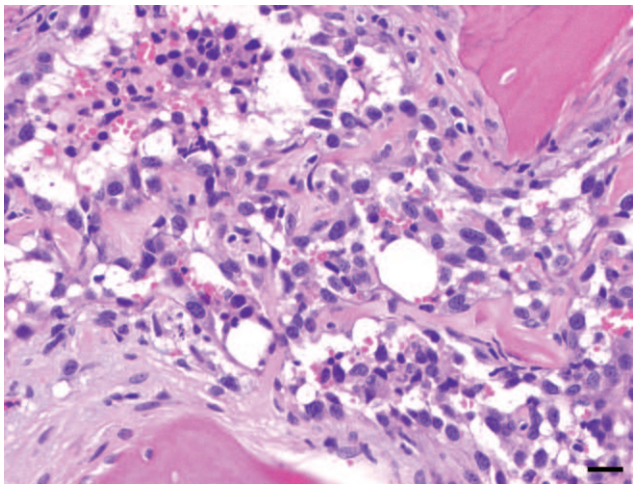

Fig. 2: Bundles and streams of pleomorphic, mesenchymal neoplastic cells infiltrate between bony fragments, producing irregular trabeculae of an eosinophilic matrix (osteoid). Haematoxylin and eosin stain. 20×; Scale bar = 50 μm.

Key points

- In veterinary medicine, radiography remains the primary imaging modality used to identify a bone tumour. Ultrasound- or radiography-guided bone biopsy can be performed to characterise the primary bone tumour ante-mortem and provide a definitive diagnosis.
- Overall, more cases are needed to determine equine osteosarcoma characteristics, including common signalment, predilection sites, tumour behaviour, systemic effects or potential treatments.
- Palliative radiation therapy should be considered as an option for osteosarcoma cases where surgical removal or debulking is not pursued. However, a larger case population is required to investigate potential benefits and risks associated with undergoing palliative radiation therapy.

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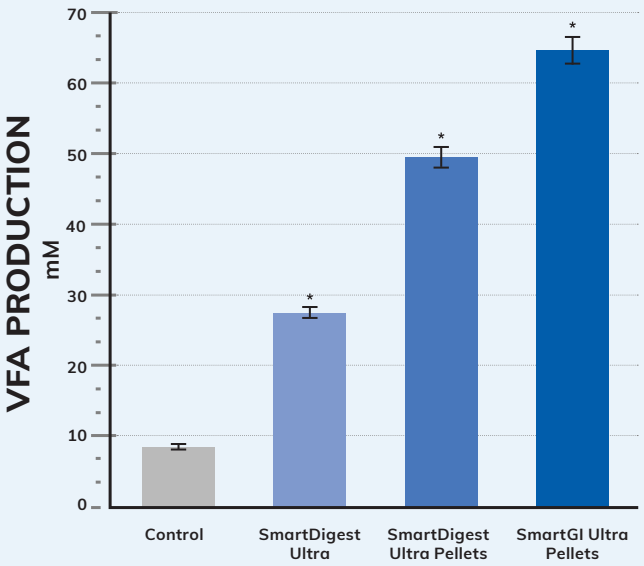

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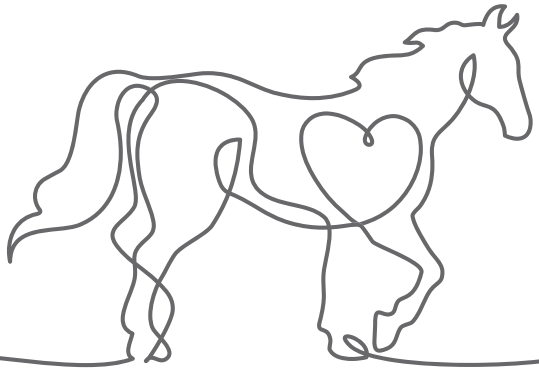

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Case Report

Post fetal death development of endometrial cups in a Jenny donkey (*Equus asinus*)

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Keywords: horse mare; Jenny donkey; extraspecies embryo transfer; conceptus; chorionic girdle; eCG

Summary

The invasive chorionic girdle portion of the equine conceptus invades the overlying maternal endometrium on or around Day 36 of gestation to form the equine chorionic gonadotrophin (eCG)-secreting endometrial cups. Endometrial cups persisting after early pregnancy loss have a significant impact on a mare's breeding potential and the continuing presence of eCG in her circulation can result in irregular ovarian activity and the repeated formation of anovulatory haemorrhagic follicles. Usually, if a mare undergoes fetal death before Day 35 postovulation it is very unlikely that she will form endometrial cups and produce eCG.

A Day 8 horse (*Equus caballus*) embryo was transferred nonsurgically to the uterus of a Jenny donkey (*E. asinus*) that had ovulated 6 days earlier. The Jenny was confirmed pregnant 3 days later and serial ultrasonographic examinations of her uterus between Days 11 and 28 showed a normal looking conceptus except that the embryo, which showed a heartbeat from day 22, was situated dorsally within the conceptus. A heartbeat was confirmed on Days 25 and 28 but this had ceased on Day 33 when Doppler showed an absence of any blood flow within the conceptus. Further ultrasound scans of the uterus on Days 34, 36, 39 and 42 revealed a dead fetus and a collapsing conceptus. However, despite fetal death having occurred between Days 28 and 33 of gestation the horse chorionic girdle remained viable to invade the endometrium and form a circle of typically large eCG-secreting horse endometrial cups in the right uterine horn (**Fig 1**).

The high concentrations of horse eCG secreted by these cups, with its higher FSH-to-LH ratio compared to donkey eCG, hyper-stimulated the donkey's ovaries to produce multiple large secondary follicles (**Fig 2**) and resulting accessory corpora lutea that secreted high concentrations of progestagens which persisted in her bloodstream for the next 90 days. This case illustrated that, in all likelihood, invasion of the chorionic girdle can still occur after death of the fetus thereby indicating its considerable autonomy.

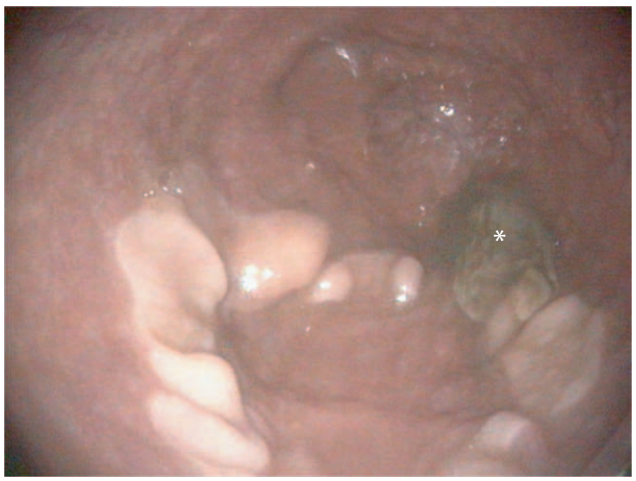

Fig. 1: Hysteroscopic examination of the interior of the left uterine horn on Day 49 postovulation to show the typically large, horse endometrial cups beyond which the fetal embryonic membranes lie collapsed on the uterine floor (asterisk).

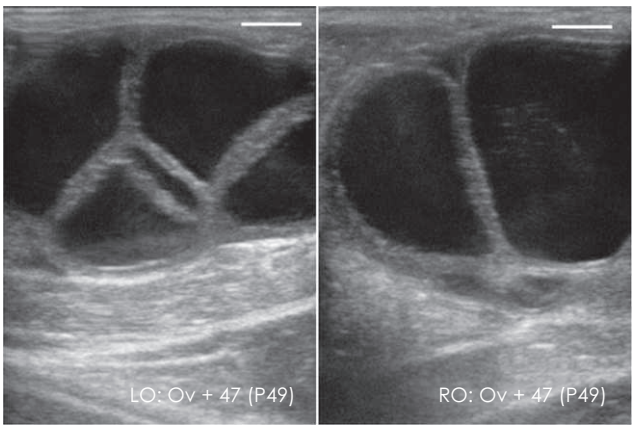

Fig. 2: The ovaries of the Jenny donkey at Day 47. Both have been hyper-stimulated by the horse eCG circulating in the donkey's bloodstream and they show multiple large follicles (scale bar = 1cm).

Key points

- Invasion of the chorionic girdle and subsequent development of endometrial cups in the maternal endometrium can occur in the absence of a viable embryo.
- Transfer of a horse embryo to a donkey uterus and the resulting production of horse eCG, even after fetal death, resulted in hyperstimulation of the donkey's ovaries.
- It may be prudent to flush from the uterus conceptuses that fail close to the time the chorionic girdle invasion of the endometrium.

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Clinical Commentary

Liberated from the girdle: The life and impacts of endometrial cups

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Significant work has been undertaken to characterise the means by which the baton of progestogenic support of pregnancy is passed from primary corpus luteum to accessory corpora lutea to fetoplacental unit with the ultimate goal of achieving a healthy foal. First described in 1912, with their functionality elucidated and reported in 1943, the endometrial cups of equine pregnancy serve a vital role in this relay (Schauder 1912; Cole and Goss 1943). Formed from the invasion of maternal endometrium by trophoblast cells of the chorionic girdle, the endometrial cups secrete equine chorionic gonadotropin (eCG, also known as pregnant mare serum gonadotropin, PMSG) which in turn promotes the development of accessory corpora lutea.

The case report described in this issue (Wilsher *et al*. 2021) adds to the body of work surrounding the unique mechanisms of maintenance of pregnancy in the mare by providing supportive evidence that the invasive cells of the chorionic girdle are potentially autonomous and able to enact their effects on the endometrium even in the face of embryonic death. Gene transcription for eCG is evident by Day 30 of gestation in conceptus membranes (McDowell *et al*. 1993), and eCG is detectable in chorionic girdle cells as early as 32 days post-ovulation (Wooding *et al*. 2001). Both of these events occur prior to endometrial invasion by trophoblast cells or detection of eCG in peripheral circulation. These documented landmarks may be part of the cascade of events set in motion during the late embryonic stage which provide for the independent behaviour of chorionic girdle cells described in the current case report. Further evidence for the dogged independence of chorionic girdle cells is provided by ectopic transplantation experiments in which chorionic girdle cells demonstrated invasive behaviour similar to that displayed in the uterus when placed in recipient skin and mucosa (Adams and Antczak 2001).

In a species with otherwise relatively superficial placentation (epitheliochorial cf. haemochorial), the invasive trophoblast cells of the chorionic girdle initiate the most intimate attachment between the mare's uterus and her developing fetus. Species which rely on epitheliochorial placentation (such as equids) keep maternal and fetal blood at relative arm's length, separated by six tissue layers. On the other end of the spectrum, haemochorial placentation (displayed by humans and rodents, e.g.) is a warm and deep embrace, with fetal chorionic epithelium in direct contact with maternal blood. These stark differences carry implications for communication between the maternal and fetal environments including nutrient and waste exchange, immunologic tolerance and uterine remodelling during and after gestation. Chorionic girdle cells can be thought of as satellite cells deployed by the conceptus on a mission to secure the continued survival of their source. Once this operation has been launched, the current case report would support the theory that they have the ability to continue their function despite the demise of their embryologic home base.

In contrast to many other endocrine structures, the surrounding vasculature of the endometrial cups is sparse (Enders *et al*. 1995). This feature may serve as a self-limiting valve of information both to and from the endometrial cups to allow only a trickle of immunologic signalling to be transmitted, and thereby stave off the maternal cell-mediated immune response which culminates in their degeneration and death by approximately 120 days of gestation. Certainly, this is not the only mechanism by which this achieved, but rather a potential supporting player. The existence of an extensive and exquisitely balanced immunologic duet between mare and endometrial cups which achieves a time limited tolerance of the semi-allogeneic endometrial cups has captured the attention of researchers in recent decades (reviewed Antczak 2020). After endometrial cups have formed and the mare is exposed to eCG, her breeding season is traditionally thought to be effectively ended due to the impacts of eCG on normal cyclicity. This has been challenged by recent work documenting a pregnancy rate of 45.5% (10/22) in mares who had undergone induced abortion at 70–77 days of gestation (Estradé *et al*. 2016). In the ten mares that became pregnant compared to the 12 that did not, those that became pregnant had significantly lower circulating concentrations of eCG prior to induced abortion. In this work, the mean interval from abortion to first ovulation in the mares that resumed cyclicity was 34 days, with a range of 11–60 days (Estradé *et al*. 2016). In industries with strong pressure for foals to be born early in the year, this additional waiting time is highly undesirable. Unless abortion was to occur early in the breeding season, this delay would preclude a rebreeding attempt in many cases.

Although critically important in the maintenance of equine pregnancy, the overzealous endometrial cup has the potential to cause clinical frustration when it persists beyond its usual lifespan. Persistent endometrial cups have been reported sporadically in the literature (Mitchell and Betteridge 1972; Willis and Riddle 2005; Steiner *et al*. 2006; Allen *et al*. 2007; Wolfsdorf *et al*. 2008; Allen and Wilsher 2011; Crabtree *et al*. 2011), with mainstays of diagnosis being the detection of PMSG in blood coupled with visualisation of the structures during hysteroscopy. Occasionally, retained endometrial cups may be seen using transrectal ultrasonography of the uterus, but this is a less sensitive diagnostic for the condition (Podico *et al*. 2020). Mares with continued exposure to eCG secreted by persistent endometrial cups typically present for failure to cycle reliably and development of anovulatory follicles.

Potential management options for retained endometrial cups include chemical curettage by infusion of kerosene, laser ablation and direct removal during hysteroscopy.

Crabtree *et al*. (2011) demonstrated kerosene infusion to be effective in abruptly reducing circulating concentrations of eCG in two mares, which is in contrast to the findings of Podico *et al*. (2020) who reported no difference in endometrial cup retention in mares infused with kerosene versus saline. A key difference in case selection between these works explaining this disparity may be that the earlier work described two cases of endometrial cups which had overstayed their lifespan in the uterus, whereas the more recent undertaking was attempting to disrupt endometrial cups which were within appropriate physiologic age. One could speculate that the aged cups were already partially degraded and more vulnerable to the effects of kerosene than those more freshly rooted.

Of final clinical note, eCG offers a serviceable method of pregnancy diagnosis in mares, especially in situations in which ultrasound is unavailable, impractical or unsafe. The utility of this method is limited in that it does not document embryonic or fetal viability (beautifully illustrated in the findings of the current case report) and is only valid for a finite window during gestation. False positives are possible due to the cross-reactivity of luteinising hormone with PMSG in traditional testing assays.

Despite the considerable work that has been devoted to understanding the means and mechanisms underlying pregnancy in the mare, the case report described herein emphasises the humbling fact that there are still intriguing details left to be unearthed. Further documentation of interesting cases which bring to light new aspects of pregnancy development is critical to continuing this discovery process.

Author's declaration of interests

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Ethical animal research

Not required for this clinical commentary.

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Case Report

Advanced imaging of a histologically confirmed bone infarction of the distal tibia in a Warmblood mare

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Keywords: horse; osteonecrosis; bone pathology; computed tomography; histopathology

Summary

An 8-year-old Warmblood-cross mare presented for investigation of acute onset left hindlimb lameness. Manipulation of the limbs revealed that the mare was reluctant to pick up the left hindlimb. Dynamic examination revealed a moderate (3/5, AAEP) left hindlimb lameness. Nuclear scintigraphy identified a marked, focal increase in radiopharmaceutical uptake in the distal aspect of the left tibia. Radiography revealed a large, oval, multiloculated radiolucent area within the medulla of the distal metaphysis of the left tibia (**Fig 1**). The radiolucent area had an irregular trabecular pattern, bordered by a narrow, radiodense rim. The owner elected conservative treatment, so box rest was advised for the first 6 weeks followed by small paddock turnout for 6 months. At reassessment, although the mare tolerated manipulation of the left hindlimb better, the lameness was unchanged. Gamma scintigraphy and radiography of the lesion were similar to the initial presentation. As the mare was still lame, the owner declined further treatment and elected euthanasia. Post-mortem computed tomography of the limb revealed a large, oval hypoattenuating area within the distal tibia, surrounded by a thick, irregular and sclerotic border. The lesion occupied the majority of the medullary cavity of the distal metaphysis and epiphysis of the tibia. No involvement of cortical bone was evident. Macroscopic examination revealed an oval-shaped lesion with a cream-coloured centre and diffusely orange rim, located in the medulla of the distal metaphysis of the left tibia with no involvement of the adjacent cortical bone (**Fig 2**). The surface of the tibiotarsal joint was unremarkable with no evidence of articular cartilage damage. Regional blood vessels were grossly unremarkable with no evidence of thrombosis/vasculitis. Histopathology revealed rarefied trabeculae showing a reduction in size with jagged outlines, empty lacunae and no bone-lining cells, consistent with necrotic bone. The dilated medullary cavities were filled with mature adipocytes, showing occasional hypereosinophilic, irregular granular material consistent with necrotic adipocyte debris. The outer rim of the lesion was characterised by dense, haphazardly arranged bundles of collagen with proliferating spindle cells, multiple, multinucleated cells and macrophages. No signs of osteomyelitis or neoplasia were observed. The gross and histological morphology was consistent with bone infarction.

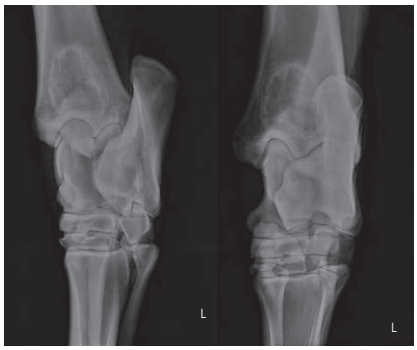

Fig 1: Dorsolateral-plantaromedial oblique radiograph of the left hock showing the large, oval, multiloculated radiolucent area within the distal metaphysis of the tibia.

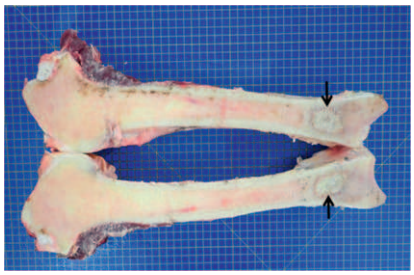

Fig 2: Longitudinal section of the left tibia, revealing a focal, oval medullary lesion on the distal metaphysis (arrows).

Key points

- Bone infarction (osteonecrosis) is an uncommon cause of lameness, most commonly affecting long bones such as the tibia
- Bone infarction can be established as a clinical diagnosis using nuclear scintigraphic, radiographic and computed tomographic findings.
- Histopathology remains essential to make a definitive diagnosis and to differentiate between bone infarction and aneurysmal bone cysts.

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Clinical Commentary

Update on advanced imaging techniques applicable for lesions within long bones in equines

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The case report by Hann *et al*. (2021) in this issue describes advanced imaging of a bone infarction of the distal tibia in a Warmblood mare, histologically confirmed at post-mortem. The initial lameness investigation described is one which experienced hospital- or clinic-based lameness clinicians will be familiar with; a horse presents with a baseline unilateral hindlimb lameness and is too difficult or dangerous to perform regional anaesthesia, which would ideally have been the next step. One means to progress the investigation is to perform nuclear scintigraphy to try to localise area(s) of abnormality. In this case, identification of a single focal area of significantly increased radiopharmaceutical uptake (IRU) on scintigrams allowed for discrete radiography of the distal tibia to be performed and an obvious lesion correlating with the location of abnormal IRU on scintigrams was identified on radiographs. Accurate identification of the pathology causing the abnormal imaging appearance is a constructive next aim, allowing for diagnosis and prognosis, which will influence treatment options. Whilst the lesion was clear to see, its appearance was not pathognomonic for any one condition, making it impossible to diagnose or prognosticate for the horse. Biopsy of the lesion to determine the cellular make-up of the lesion would have been informative and potentially diagnostic; however, a conservative route of rest and time was opted for by the owner. At this stage in an investigation, clinicians must draw upon the peer-reviewed veterinary literature to try to compare the current case with those previously described.

There are similarities between the case reported by Hann *et al*. (2021) and the case described by Sánchez *et al*. (2010), both of which underwent euthanasia, and the case described by Stöcker *et al*. (2015) which made good clinical progress following treatment. These cases presented with hindlimb lameness in a mature horse, with location of a lesion visible on radiographs as a clearly marginated radiolucent area within the distal tibial metaphysis. It is worth noting, however, that the lesion within the tibia was considered incidental by Sánchez *et al*. (2010), whom had localised lameness to within the tarsal joints, where extensive degenerative joint disease was identified on radiographs. Two further case reports are discussed by Hann *et al*. (2021); however, in these two cases multiple bones were affected, suggestive of a systemic disturbance and likely a different aetiology to that in the horse reported (Fenger *et al*. 1993; Martig *et al*. 2008).

The past decade has seen the rapid development of imaging modalities within equine veterinary medicine, from progression to clinical use of robotic technology for the acquisition of radiographs within radiology suites to increased availability of wide bore CT systems, facilitating imaging of the equine stifle and the entire equine cervical spine, improved capability for image acquisition of more proximal regions of the equine limbs within both a low-field standing MRI system and high-field MRI systems under general anaesthesia (GA), to development of standing CT scanners and most recently development of PET scanners capable of imaging much of the equine limbs. In addition to the rapid development of advanced diagnostic imaging equipment suitable for the horse, there has been development and refinement of specific techniques for imaging the horse within these modalities, with more accurate interpretation in mind (Spriet *et al*. 2008, 2019; Nelson *et al*. 2017). The option of accurate co-registration of images from one modality with another is enhancing our diagnostic capability further.

Can any one or combination of advanced imaging modalities allow us to understand more about the tissue composition of unusual lesions such as the one in this case report and predict how such a lesion might progress, and can this help us to prognosticate regarding such lesions?

Gamma cameras detect emission of gamma rays, emitted when there is presence of a radionuclide in tissues. If we attach the radionuclide to a radiopharmaceutical which localises to a target organ or tissue under investigation, then we can detect the activity of the physiological processes within these organs or tissue under investigation. In equine hospitals and clinics, the radionuclide technetium linked to the radiopharmaceutical methylene diphosphonate (MDP) is most commonly used for nuclear scintigraphy. MDP binds to exposed hydroxyapatite scaffold within bone in a concentration which is directly relative to the osteoblastic activity within the bone at the time of the administration (Driver 2004; Zhing *et al*. 2015). Images from the first bone scan of the horse reported by Hann *et al*. (2021) showed significant IRU within the distal metaphysis of the tibia. Six months later, the second set of scintigrams showed much milder IRU in this region, and an impression of increased radio-opacity was noted within the region on repeat radiographs. We can assume that at the time of the first bone scan there was significant localised exposure of hydroxyapatite scaffold and significant osteoblastic activity within the trabecular bone within the lesion. Six months later, gross and histopathologic examination of the lesion post-mortem showed that the trabecular bone scaffold had been largely replaced by necrotic bone and adipocytes. It is plausible that deposition of new bone adjacent to the area of damaged bone, leading to increased sclerosis at the

margin of the lesion and limited neovascularisation into the lesion were responsible for progression to necrosis of the tissue contained within the sclerotic margin. A CT examination performed post-mortem identified a thick sclerotic margin to the lesion compared with the narrow radiodense rim delineating the lesion on initial radiographs. The results of the second bone scan may have been misleading antemortem, and in the light of the horse's clinical improvement also, potentially interpreted as a positive result, suggestive of some resolution of the lesion rather than its progression to a necrotic lesion. It is important to remember that whilst abnormal IRU may well subside as an area of damaged bone heals, it will also subside as the vascularity to an area diminishes. In humans, radionuclide uptake in bone marrow and within the bony skeleton may be compared using sequential scanning, and the combination of reduced uptake within marrow and abnormal uptake within the skeleton is considered typical of infarction rather than infection (Skaggs *et al*. 2001). This may be a technique which equine hospital clinicians can adopt and utilise when follow-up nuclear scintigraphy is being considered to evaluate progression of specific lesions.

The case described by Stöcker *et al*. (2015) was initially treated with bisphosphonate. In humans, bisphosphonates are implicated as a potential risk factor for development of a bone infarct (Dodson 2009). The horse went on to develop poorly defined increased sclerosis within the previously lucent region, identified at CT prior to surgery some 3 months later (Stöcker *et al*. 2015). Following transcortical biopsy and curettage of the lesion and graft placement, the horse made steady progress and eventually returned to work. It is not clear whether treatment with bisphosphonates helped or hindered the process of remodelling of the abnormal region, but it is highly likely that curettage and introduction of bone marrow grafts were beneficial, as both procedures are known to influence neovascularisation.

CT was performed on the limb post-mortem by Hann *et al*. (2021), and in the case reported by Stöcker *et al*. (2015), prior to surgical biopsy. In the latter, CT allowed for selection of the optimal site for biopsy of the lesion prior to curettage and packing with bone marrow, but other than improving our knowledge of the spatial location of the lesion, native phase CT did not help to further understand the pathologic process.

The technique of contrast CT was developed in order to more clearly visualise and evaluate soft tissues, and in this way better identify the presence of pathology within soft tissues on CT images. Contrast CT is routinely performed in small animal studies, but the horse provides some challenges. Because of the sheer size of the horse, the volume of contrast agent which can be administered rapidly intravenously, as is required for delivery of a bolus, is far less than the calculated mg/kg bwt systemic dose. Successful contrast-enhanced CT imaging in the horse therefore relies on intra-arterial delivery of a bolus of contrast agent into an artery which is comparatively local to the region of interest. Clinical use of contrast CT of the equine distal limb is well described in the literature. Torrent *et al*. (2019) recently described techniques for the catheterisation of the cranial tibial artery and injection of an iodinated contrast agent in research horses using ultrasound guidance during a first study under GA, followed by a second phase of the study using ultrasound guidance in horses under standing sedation, followed by a third study whereby Technetium-HMPAO labelled allogenic bone marrow derived equine MSC were injected under standing sedation using the same technique. This method could be used to enable contrast-enhanced CT imaging of the distal tibia and tarsus in the horse, and we might expect to see a pattern of contrast enhancement which is restricted to the periphery of a bone infarct, compared with a more generalised pattern of contrast distribution within an early neoplastic lesion or an ossifying fibroma.

The MRI appearance of a bone infarct in humans is considered typical, if not quite pathognomonic, and MRI is considered essential for the diagnosis of osteonecrosis in humans (Saini and Saifuddin 2004). Contrast enhancement with intravenous gadolinium has been used during the MRI examination as a means of differentiating hypervascularised viable tissue from hypovascularised necrotic tissue; however, this differentiation can be made without the use of contrast agents. For example, viable areas of trabecular bone within the femoral head demonstrated low signal intensity on T1 weighted and intermediate or high signal intensity on T2 weighted pulse sequences, whereas necrotic areas appeared hypointense on both weightings and also on short tau inversion recovery (STIR) sequences, acquired without the use of contrast (Saini and Saifuddin 2004). These pulse sequences are all currently routinely used to image the equine limb in various MRI systems.

The 'double-line sign' is described as a virtually diagnostic change seen adjacent to areas of necrotic bone on T2 weighted spin echo sequences, occurring at the interface between viable and nonviable tissue. It consists of an outer low signal rim (corresponding to sclerotic bone) with an inner rim of high SI (corresponding to vascularised granulation tissue and/or chondroid metaplasia). Chemical shift artefact contributes to this appearance, but does not alter its diagnostic significance (Saini and Saifuddin 2004). In adult human patients undergoing gadolinium-enhanced MRI, acute infarcts demonstrated thin, linear rim enhancement on MRI whilst osteomyelitis revealed a more irregular pattern of marrow enhancement (Umans *et al*. 2000). Magnetic resonance imaging (MRI) of the distal portion of the equine tibia is possible with various high-field MRI systems (e.g. MR-Vet; Siemens Verio)[1,2] and low field systems, and there is useful information in the literature (Barrett *et al*. 2018, Blaik *et al*. 2000). A low-field standing MRI system with a 'U'-shaped open magnet is capable of imaging up to the level of the tarsus of the hors, and such studies may include diagnostic quality images of the distal tibia in smaller and more tolerant horses[3]. The standing MRI system can rotate 90 degrees, and, in this orientation, it could be possible to image the distal tibia under GA also.

Positron emission tomography (PET) is used primarily within oncology in the human field and commonly utilised alongside CT imaging; however, 'stand alone' PET using a purpose-designed portable system is also used for imaging of the human brain. A modified portable PET system is now in use clinically in two equine centres in the USA where ^{18}F-NaF PET is currently the primary clinical application of PET scanning in the horse. ^{18}F-NaF is an excellent marker of bone remodelling, and this technique essentially provides a tomographic form of scintigraphy scan, with consequent higher spatial resolution and higher sensitivity than a conventional bone scan technique which is limited by the planar nature of the detectors. Other radioactive tracers used in PET also

concentrate in metabolically active tissues and have specific clinical applications within the medical field as a result.

To date, published clinical studies using PET in the horse have focused on the equine distal limb, but research work has been reported which will allow for PET scans of more proximal regions of the equine limb such as the distal radius and tibia (M. Spriet, personal communication). One limitation is that the internal diameter of the portable PET scanner reported is 22 cm, which is comparable to the internal diameter of a 'U'-shaped magnet designed for standing MRI of the horse[3]. The hindlimb in the horse becomes progressively more muscled proximal to the tarsus, and increasing thickness will limit the proximal extent to which either system can reach.

Was the inability to provide a clear diagnosis and prognosis for the mare a factor in the reason why the client did not persevere with treatment in spite of some apparent clinical improvement at re-examination? In summary, our ability to differentiate accurately between chronic and active lesions and lesions with some vascular supply versus those which are encapsulated in fibrous tissue or walled off within sclerotic bone and less likely to resolve without intervention is valuable information which will help better inform clients and veterinarians, and, given recent advances in equine diagnostic imaging, is becoming increasingly within our reach.

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Ethical animal research

Not applicable.

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Manufacturers' addresses

[1]Esaote, Genova, Italy.
[2]Siemens Medical Solutions USA, Inc. Malvern, Pennsylvania, USA.
[3]Hallmarq Veterinary Imaging Ltd, Guildford, Surrey, UK.

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Case Report

Fusobacterium necrophorum septic arthritis of the temporomandibular joint in an Australian Stockhorse mare

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Keywords: horse; temporomandibular joint; sepsis; osteomyelitis; *Fusobacterium necrophorum*

Summary

An 11-year-old Australian Stockhorse mare was referred for investigation of a draining tract of 1 week's duration, located caudal to the left dorsal orbit.

At presentation, purulent malodorous discharge was draining caudal to the dorsal orbit of the left eye. There was fluctuant periorbital swelling and marked pain on palpation of the area. Radiography revealed a lytic lesion of the left zygomatic process and an associated draining tract. A metallic probe confirmed communication between the cutaneous fistula and the lytic lesion (**Fig 1**). Computed tomography (CT) of the skull showed irregular lucency in the subchondral bone of the zygomatic process of the left temporal bone, with a heterogeneous irregular osseous body consistent with a sequestrum at its centre. There was also irregular osteoproliferation of the zygomatic process centred around the condylar fossa (**Fig 2**). The articular disc appeared intact.

Under general anaesthesia, the fistulous tract and necrotic bone of the zygomatic arch were debrided. A 14 gauge hypodermic needle was placed into the temporomandibular joint (TMJ) via the caudal compartment of the dorsal synovial pouch, and the TMJ was copiously lavaged with sterile saline through the needle and surgical site. A gentamicin impregnated collagen sponge was packed into the defect and the skin over the surgical site closed with 0 Nylon in a simple interrupted pattern. Culture of necrotic bone obtained during surgery yielded pure growth of *Fusobacterium necrophorum*.

Post-operatively the mare received procaine penicillin and gentamicin for 3 days. Based on culture and sensitivity results the mare was transitioned to doxycycline and metronidazole for a further 14 days.

At 6 months post-operatively, the surgical site had healed completely and the mare had returned to her prior level of work with no problems prehending or masticating.

Key points

- This is the first case report of joint sepsis in a horse where *F. necrophorum* was the sole isolated pathogen.
- Due to timely intervention, advanced imaging, and the use of culture and sensitivity, this case was managed minimally invasively and resulted in a good outcome.

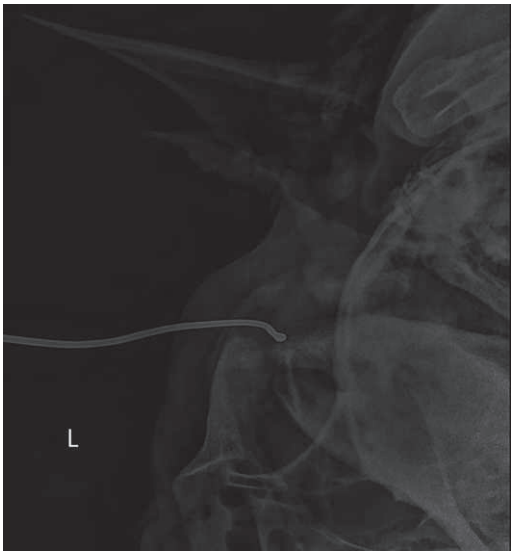

Fig 1: Oblique radiograph of the left skull showing a malleable metallic probe within the draining tract communicating with the zygomatic process.

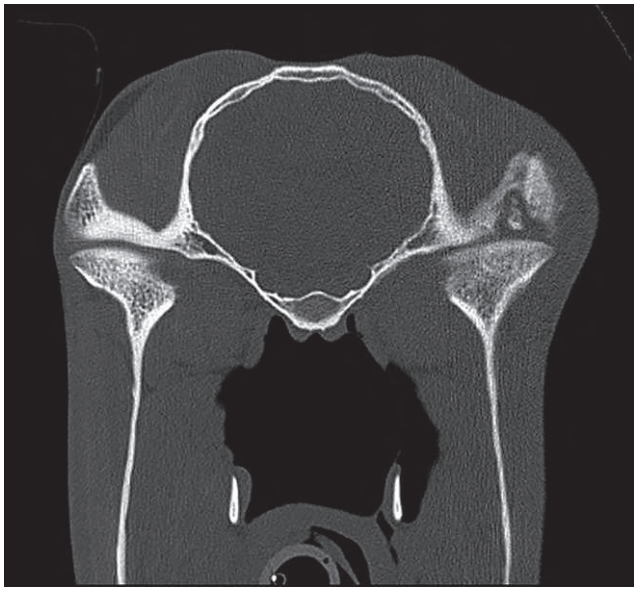

Fig 1: Transverse CT image of the skull showing irregular proliferation of the zygomatic process of the TMJ with a focal area of articular osteolysis and sequestrum formation at its centre.

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Clinical Commentary

Unusual pathogen in an unusual joint: Implications on antimicrobial resistance

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In this issue, Lean *et al*. (2021) illustrate a successful diagnosis and treatment of an uncommon case of septic osteomyelitis in a temporomandibular joint (TMJ) of a mature Australian mare caused by *Fusobacterium necrophorum*. It is an atypical case of septic arthritis not only by the anatomical location but also by the isolated micro-organism.

Among the reported diseases affecting TMJ, namely fractures, luxations or, lately, degenerative osteoarthritis (Hardy and Shiroma 1991; Devine *et al*. 2005; Sanders *et al*. 2014; Jorgensen *et al*. 2015), septic arthritis is the most pathological situation recorded in equine TMJ literature, generally as a result of a traumatic injury with or without wound presentation (Warmerdam *et al*. 1997; Carmalt and Wilson 2005; Devine *et al*. 2005; Nagy and Simhofer 2006; Barnett *et al*. 2014; Frietman *et al*. 2018; Balducci *et al*. 2021). Despite that, TMJ disorders are not frequently diagnosed in horses mainly due to the unspecific and subtle clinical signs generally exhibited that may be misleading (May *et al*. 2001; Barnett *et al*. 2014; Carmalt 2014; Sanders *et al*. 2014; Pereira *et al*. 2016). A number of anatomical and physiological reasons have been considered in order to explain such lower prevalence in diagnosing TMJ pathologies. Carmalt *et al*. (2011) described a different synovial expression of proinflammatory cytokines such as TNF-α (tumour necrosis factor), total proteins or TGF-ß (transforming growth factor) after induced lipopolysaccharide inflammation in the TMJ, in comparison with the response of the metacarpophalangeal (MCP) joint. But the findings were upsetting since the measured concentrations of these cytokines were higher in TMJs than in MCP joints, and therefore, more dramatic clinical signs would have been expected. The same group of researchers (Smyth *et al*. 2016) studied TMJ kinematics after experimentally induced synovitis. They proved that such synovitis elicited marked effusion and pain, because the majority of horses in the study changed the cycle of mastication by switching the masticatory pattern from the affected to the unaffected side. These horses also managed pain by modifying the spatial limits of the masticatory cycle and reducing bite forces during power stroke phase and closing their mouths faster; surprisingly, none of them showed avoidance to external palpation or other abnormal behavioural signs. Recently, a multi-centric study (Carmalt *et al*. 2016) revealed that 40.2% of animals imaged with computed tomography (CT) in a sample of 1018 asymptomatic TMJ horses were identified with shape and density alterations in both the mandibular condyle and the zygomatic process of the temporal bone. Different-appearance bone cysts were identified in 57.4% of horses over one year old and in 23% of older horses, but clinical significance and potential compensatory behaviours are still unexplored (**Fig 1**). Therefore, further investigations are needed to understand why and how TMJ painful disorders are better tolerated by horses and whether they may cause limitations in sport performance.

Similar to humans, TMJ pain tolerance hinders the recognition of the pathology preventing its early diagnosis and treatment unless external trauma is present. The inherent anatomical complexity of the region makes it challenging to apply conventional imaging diagnostic tools (Rodriguez *et al*. 2006, 2007; Ebling *et al*. 2009; Townsend *et al*. 2009), and computed tomography (CT) is the best method to characterise TMJ lesions as Lean *et al*. (2021) showed in their case report. CT is crucial to tailor a successful surgical plan and monitor the evolution of the disease; currently, standing CT units overcome the risks associated with general anaesthesia.

Lean *et al*. (2021) remind us of the importance of performing culture and susceptibility tests from appropriate samples. The most common isolated pathogen in septic TMJ in horses is *Streptococcus zooepidemicus* (Warmerdam *et al*. 1997; Carmalt and Wilson, 2005; Nagy and Simhofer 2006; Barnett *et al*. 2014). *Staphylococcus aureus* has also been isolated (Balducci *et al*. 2021). In human medicine, septic TMJ arthritis is considered an emergency because of the severe

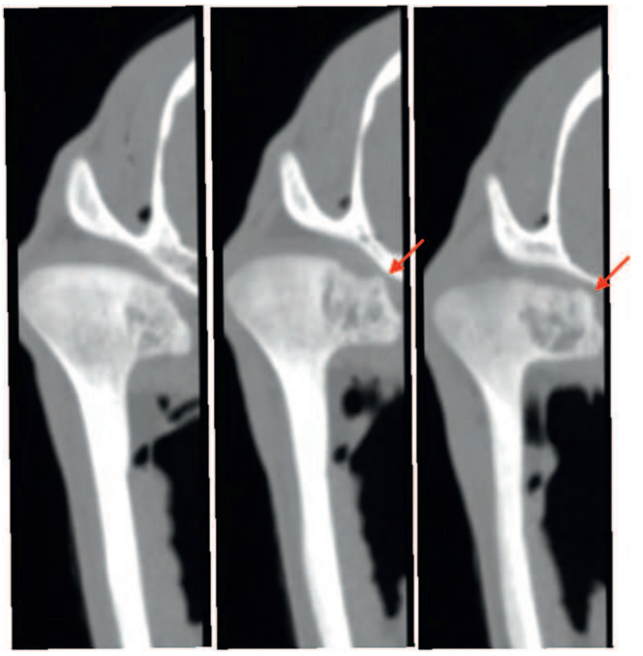

Fig 1: Transverse CT images from a 1-year-old asymptomatic horse depicting a subchondral bone lesion medially in the right mandibular condyle. Note heterogenic density appearance and the new bone formation over the medial articular condyle surface (arrow).

consequences, which may arise from its late diagnosis and treatment. The causative agents mainly isolated in people are *Staphylococcus aureus* and *saprophyticus*, *Streptococcus* spp, Neisseria, *Pseudomonas aeruginosa*, *E. coli* and *Haemophilus influenzae* (Gayle *et al*. 2013; Frojo *et al*. 2018). Although the primary source of infection is often undetermined, the most commonly reported infection has been via a haematogenous spread from distant primary infections, followed by blunt local trauma (Gayle *et al*. 2013). In the present clinical case, *Fusobacterium necrophorum* was the sole micro-organism isolated in the culture. To the author's knowledge, it is the first description found in literature where *F. necrophorum* is causing joint sepsis in both humans and equids. *Fusobacterium* spp. are part of the commensal microbiota on multiple anatomical locations, especially oral cavity and skin, in both species (Trevillian *et al*. 1998; Valentine 2008; Umaña *et al*. 2019), and they behave as opportunistic pathogens taking advantage of pre-damage tissues or previous infections (Umaña *et al*. 2019). Recent studies have shown that *Fusobacterium* spp. are genetically able to develop threatening diseases since they secrete multiple toxins: leucotoxins that are active against a variety of white blood cells; cytoplasmatic toxins; and haemolysin. Given such molecular mechanisms for pathogenesis, *F. necrophorum* has the ability to launch the tissue invasion and provoke rapid progression of lesions as the only pathogen without an underlying illness despite being opportunistic (Chukwu *et al*. 2014; Umaña *et al*. 2019). Human infections caused by *F. necrophorum* are strikingly emerging. Researchers mainly attribute this increase to the alteration in antibiotic protocols and courses. Scientific data on antibiotic sensitivity patterns of *F. necrophorum* are still scarce. Otherwise, penicillin is widely used in the treatment of *F. necrophorum* infections; clinical resistance to gentamicin and quinolone and poor susceptibility to tetracyclines have been described, but resistance to metronidazole has not been recorded yet (Chukwu *et al*. 2014).

The assumption of aforementioned scientific knowledge might lead us to implement an empirical therapy at first approach. However, if the plan fails, it may be detrimental for the animal and human welfare and is disquieting in terms of antimicrobial resistance (AMR). AMR is a global problem of growing concern. New resistance mechanisms developed by pathogens are derived, among other factors, from overuse and misuse of antibiotics not only in veterinary medicine but also in human medicine. The World Health Organization (WHO) declares that the AMR is an increasing critical problem to global public health affecting animals and humans. The morbidity and mortality rates have depicted a rapid rise, with more than 30,000 deaths per year being reported as a direct consequence of AMR infections. Moreover, AMR has a direct impact on higher total public spending on Health since patients with AMR infections require longer hospitalisation, the use of more additional diagnostic tests and the use of more expensive antibiotics for longer periods. Sadly, accordingly to WHO, 'AMR is putting the gains of the Millennium Development Goals at risk and endangers achievement of the Sustainable Development Goals'.

It is presumed that 61% of infectious micro-organisms are zoonotic from horses to humans (Lönker *et al*. 2020). The concerning issue is that such zoonotic micro-organisms are developing AMR not only for one drug but also for multiple drugs (multi-drug resistance (MDR)). And this MDR pathogens also transfer the developed resistance mechanisms from one specie to another. That will have a great impact on the control and treatment of the nosocomial infections in hospitals (Bourély *et al*. 2020; Lönker *et al*. 2020). There are few published investigations dealing with the AMR in the most frequent equine pathogens. In a recent survey carried out on an equine population in France, MDR was found to be of 10% for isolated *Streptococcus* spp., 16.5% for *E. coli* and 22.5% for *Staphylococcus aureus*, which was the highest value (Bourély *et al*. 2020). Generally, special attention has been paid to extended-spectrum b-lactamase (ESBL)-producing Enterobacteriaceae, Meticillin-resistant *Staphylococcus aureus* (MRSA) and multi-drug-resistant Salmonella due to their implication in nosocomial diseases (Walther *et al*. 2017; Bourély *et al*. 2020). Walther *et al*. (2017) collected data from a study in which 41.3% of infected wounds were caused by MRSA. Conversely, current investigation concerning surgical site infection (SSI) in laparotomy midline incisions (Isgren *et al*. 2019) showed a low prevalence of ESBL-producing Enterobacteriaceae and MRSA as a causal pathogen but a greater prevalence of other MDR pathogens not previously detected in the serial swab cultures performed (**Fig 2**). All these latter findings might mislead us to select a second-line antibiotics as a first choice to treat primary infections favouring a rapid increase in resistance on such drugs. Fortunately, traditional antibiotic combinations, namely parenteral penicillin and gentamicin and oral trimethoprim–sulfadiazine (TMPS), are still effective as Potier and Durham (2020) have demonstrated. In their research, 91% of the ambulatory isolates tested and 64% of the hospital isolates were sensitive to P-G combination, and 82% ambulatory and 56% referral hospital isolates were sensitive to TMPS. The higher resistance prevalence found in equine hospital population probably comes from the antimicrobial pressure among hospital bacterial or resistant determinants among hospitalised horses (Potier and Durham 2020). Also, host's immunity, bacterial clearance, pharmacokinetics and pharmacodynamic properties of the antibiotics and synergistic or antagonistic drug interactions play a key role in the antimicrobial activity despite its in vitro resistance results or vice versa.

Antimicrobial resistance and MDR pathogens are nowadays included in the One Health issue. It is imperative to initiate a co-ordinated action from all governments and institutions to address this complex problem. The governments are required to provide greater innovation and investment in

Fig 2: SSI in a laparotomy midline incision where multi-drug resistance MRSA was isolated as a sole causal agent. Susceptibility test showed resistance to penicillins, cephalosporins, tetracyclines, quinolone and aminoglycosides.

the research to develop a new generation of antibiotics and to implement monitoring and surveillance strategies, which help veterinary and human professionals to adopt judicious and sound scientific principles for the prevention and treatment of the old and new emerging diseases.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

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Case Report

Successful outcome after surgical correction of large colon atresia in a colt foal

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Keywords: horse; atresia; colic; anastomosis; foal; congenital

Summary

A 24-h-old Warmblood colt was referred with signs of unrelenting abdominal pain and a suspicion of meconium impaction. Standing abdominal radiographs showed a large amount (25 cm length × 10 cm height) of well-formed granular soft tissue material along the ventral part of the cranial and central abdomen, consistent with meconium in the large colon. Furthermore, gas-filled and -dilated small intestinal loops with fluid creating unequal levels were observed. Ultrasonography showed fluid-dilated small intestines with reduced or absent peristalsis. The large intestines contained gas and echogenic content surrounding hypoechoic rounded structures. Despite initial medical treatment for a severe meconium impaction, the foal deteriorated and surgery was recommended. A midline celiotomy with umbilical resection was performed. Exploration of the colon revealed an atretic segment between the left ventral large colon (LVC) and the left dorsal large colon (LDC), evident as a 5 cm long band of fibrous tissue with no identifiable lumen, connecting two blind ends of colon with lumen and intact mesentery (**Fig 1**). The remainder of the large colon aboral to the lesion was deemed hypoplastic with a patent lumen and a diameter of approximately 3 cm. The caecum and ventral segments of the large colon contained a large amount of meconium, which was expelled via an enterotomy. The atresia was surgically corrected by performing a stapled side-to-side anastomosis between the lateral and dorsal taenia of the LVC and the lateral wall of the LDC using an anastomosis stapler (ILA-100) with 4.8 mm staples. The blind segments of the LVC and LDC aboral to the new stoma were resected using the anastomotic stapler, and oversewn. Based on clinical and surgical findings, the foal was diagnosed with congenital type 2 colonic atresia.

Post-operatively, the foal was ambulating well and showed no abdominal discomfort. After 24 h, it developed watery, fibrous diarrhoea, which firmed up over the following 9 days, and fluid boluses could be stopped. Twelve days after surgery, the foal was discharged. Twenty-two months after discharge, the owner reported that the foal was developing as expected, but suffered a mild, self-limiting colic episode at 20 months of age.

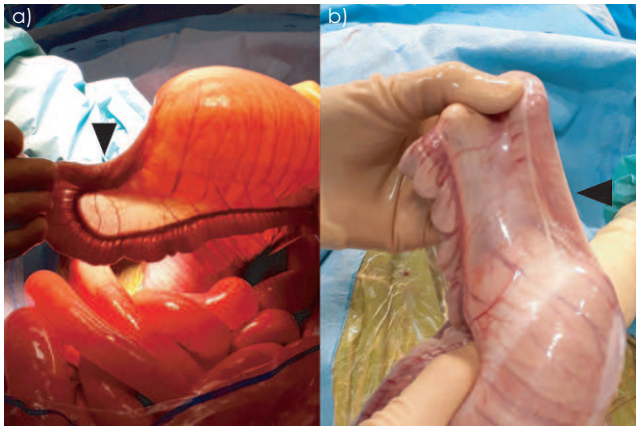

Fig 1: The gas-distended, ventral, left large colon, and atretic segment (black arrow heads) is shown.

Key points

- Diagnosis of colon atresia can be challenging depending on lesion localisation, but a large amount of meconium in the ventral abdomen and generalised signs of ileus could be an indication, as seen in our case.
- Surgical repair of large colon atresia in foals can be successful if the segments to be anastomosed are viable, easily accessible and apposable, and no other pathological findings are present.
- Stapled side-to-side colon anastomosis without oversewing might be a viable alternative in foals, if there are no pathological changes in the colon tissue to be anastomosed and the segments are easily apposable.

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Clinical Commentary

Intestinal atresia in foals: A diagnostic and treatment challenge

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Keywords: horse; foal; abdomen; colic; intestinal atresia; surgery

Intestinal atresia or agenesis is rare in foals, with a reported prevalence of 0.44-3.1% (Crowe and Swerczek 1985; Nappert *et al*. 1992). It can affect any segment of the large colon, small colon or rectum (Schneider *et al*. 1981; Nappert *et al*. 1992; Young *et al*. 1992; Turek and Verhoeven 2008; Biasutti *et al*. 2017). The large colon and pelvic flexure are the most commonly affected segments followed by the transverse colon and rectum (Nappert *et al*. 1992; Young *et al*. 1992; Turek and Verhoeven 2008). Atresia is often categorised into three different types depending on the degree of luminal obstruction (Van der Gaag and Tibboel 1980; Rakestraw and Hardy 2012). Type I describes obstruction of a normal lumen by a membrane (Van der Gaag and Tibboel 1980). Type 2 is where the oral and aboral intestinal ends are atretic and separated by some distance, but attached by a fibrous band with the mesentery intact (Rakestraw and Hardy 2012). Type 3 describes the complete absence of a segment of intestine and its associated mesentery (Rakestraw and Hardy 2012). Type 3 can be further subdivided into two sub-types, a and b, based on the presence or absence of intestine distal to the missing segment. Atresia implies that there has been a closure of a normally developed lumen so in foals with type 3 developmental intestinal abnormalities, agenesis may be a more correct definition (Schneider *et al*. 1981; Biasutti *et al*. 2017).

Intestinal atresia is fatal if untreated, so early diagnosis and surgical intervention are important for a successful outcome (Cable *et al*. 1997; Chaffin and Cohen 1999). However, reaching a diagnosis prior to surgery is often difficult, and a definitive diagnosis may not be made until the foal deteriorates clinically and an exploratory laparotomy is performed. Adding to the diagnostic challenge, is that there are a variety of conditions that cause abdominal pain in foals including meconium impaction, colitis, gastrointestinal ulceration, abdominal or umbilical hernia, intestinal strangulation or visceral rupture (Chaffin and Cohen 1999). The most common cause of abdominal pain and distension in foals in the first 12-48 h after birth is meconium impaction. In the first 24 h of life, the development of progressive pain and abdominal distension and a failure to pass meconium, often despite multiple enemas, are common to the clinical history of foals presenting with meconium impaction and intestinal atresia (Crowe and Swerczek 1985). To further complicate diagnosis, foals with intestinal atresia may also present with signs of meconium staining around the tail. This staining is associated with mucosal turnover and secretions that accumulate aboral to the abnormal segment during gestation. While these foals with intestinal atresia, even on careful questioning, will not have been seen to pass any significant volume of meconium since birth, the presence of meconium staining may provide enough confusion to delay a diagnosis and further investigation.

A complete clinical examination of a newborn foal with signs of abdominal pain should include digital palpation of the rectum. In foals with intestinal atresia, this will reveal an absence of retained meconium. Both radiography and ultrasonography of the abdomen are readily available in practice and are commonly used to provide valuable information in foals with suspected meconium impaction that is refractory to treatment (Fischer *et al*. 1987; Neal 2003; Biasutti *et al*. 2017). Typically, in the abdominal radiographs of foals with a meconium impaction, there is a tubular soft tissue opacity associated with the accumulated meconium in the small colon that can be traced to the caudodorsal abdomen. Dilated, gas-filled loops of intestine, particularly large intestine, proximal to the obstruction are commonly identified on radiographs and ultrasound examination. In contrast, in foals with intestinal atresia, an empty small colon and a granular soft tissue opacity or tubular mass in the cranioventral abdomen aboral to the atretic segment of large intestine, and gas distension of the caecum and fluid and gas-filled proximal small intestine is often a feature. Retrograde, positive contrast colonography using aqueous iodinated contrast media or 30% w/v barium at a dose rate of 5-20 mg/kg bwt instilled into the small colon through a cuffed, appropriately sized, Foley catheter inserted through the rectum has also been described (Fischer and Yarbrough 1995; Biasutti *et al*. 2017). Retrograde colonography has been reported to have 100% sensitivity and 100% specificity for a diagnosis of atresia of the transverse and small colon in foals less than 30 days of age, and 86% sensitivity for conditions affecting the large and small colons. The value of retrograde colonography diminishes in obstructions proximal to the transverse colon and where the volume of contrast media instilled is insufficient to reach the proximal small colon to provide a diagnostic image (Fischer and Yarbrough 1995; Biasutti *et al*. 2017). Oral contrast studies are not useful in intestinal atresia in the foal because ileus of the intestine proximal to the atretic segment limits the aboral passage of contrast media to the site of atresia in the large intestine.

Colonoscopy may be useful in foals with lesions located <30 cm from the anus (Overbaugh 1983; Young *et al*. 1992; Hunter and Belgrave 2010). Butylscopalammonium bromide (0.3 mg/kg bwt i.v.) may be used to suppress normal peristalsis and improve visualisation if given before the procedure (Hunter and Belgrave 2010). Colonoscopy can distinguish obstructions such as meconium impaction from atresia, however, often the atresia is too far proximal for

colonoscopy to contribute to a definitive diagnosis prior to surgery.

Using a combination of the diagnostic techniques described above, for investigation of foals presenting with abdominal pain, may still not provide a definitive diagnosis of intestinal atresia, however, are likely to provide a high index of suspicion and sufficient evidence to proceed to exploratory laparotomy (Fischer and Yarbrough 1995; Chaffin and Cohen 1999; Neal 2003; Biasutti *et al*. 2017). Generally, the prognosis for foals with intestinal atresia has been reported to be poor and there are only a few reports of successful surgical correction and, of these, there are few with long term follow-up (Schneider *et al*. 1981; Young *et al*. 1992; Nappert *et al*. 1992; Biasutti *et al*. 2017). The best surgical candidates are those where a diagnosis is made or suspected before the foal becomes systemically compromised and where the affected segment is not too long and both blind ends are accessible, and of sufficient diameter, to enable anastomosis (Prange 2013). A variety of hand sewn and stapled anastomotic techniques have been described and are usually adapted to the specific presentation at surgery. Ideally, the two affected ends should be of similar diameter or, alternatively, the technique used for anastomosis should compensate for the disparity. Anatomically and functionally, the two segments of intestine to be anastomosed should be aligned to allow effective peristalsis and movement of ingesta across the anastomosis from the proximal to distal, without risk of obstruction as the foal grows.

The case presented by Skov Hansen *et al*. (2021) in this edition of Equine Veterinary Education very clearly highlights the clinical challenges in reaching an early diagnosis, or suspected diagnosis, in foals with intestinal atresia. The foal in this case report presented to the referral hospital 24 h after birth with a history of signs of abdominal pain, refractory to pain relief, that had progressed to lethargy but with elevated vital signs on presentation. Clear evidence of the foal passing meconium after birth was not ascertained, but there was evidence of meconium staining around the hind end. The referring veterinarian treated the foal for meconium impaction with multiple enemas without success, so the foal was referred for specialist treatment.

At the referral hospital, there was no evidence of retained meconium in the distal small colon or rectum on digital examination. There was no meconium present in the small colon in abdominal radiographs. There was meconium accumulated in the large colon in the cranial and ventral abdomen. This was suspected to be in the sternal or diaphragmatic flexure. The caecum was gas filled, and fluid accumulation in the small intestine was consistent with an ileus. With the benefit of hindsight, the clinical presentation to this point suggested an obstruction distal to the meconium accumulation in the colon, consistent with intestinal atresia.

Ultrasound examination of the abdomen mirrored the radiographic findings and a 'high' meconium impaction of the large colon was suspected. So, the treatment for meconium impaction was continued and appropriate supportive treatment was commenced for a further 24 h. Ongoing deterioration in the foal's condition and failure to respond to treatment prompted surgical investigation. Positive contrast, retrograde colonography or colonoscopy were not considered in this foal, but it is unlikely, given the site of the atresia in the pelvic flexure, these diagnostic techniques would have contributed to a presurgical diagnosis.

An exploratory laparotomy was performed and the left ventral colon, proximal to the atretic pelvic flexure, was found to be dilated, while the left dorsal colon distal to the atretic segment was markedly hypoplastic. This raised concerns that an anastomosis between the dilated left ventral colon, and the hypoplastic left dorsal colon may predispose the foal to developing a functional obstruction, post-operatively. To avoid restricting the luminal diameter further, the surgeons elected not to oversew the site of the anastomosis. Oversewing the anastomoses is recommended to increase the physical support for the anastomosis and decreases the risk of dehiscence of the staple line and leaking of intestinal contents (Rakestraw and Hardy 2012). Despite the concerns with regards to the difference in luminal diameter and the reduced support, this foal responded well to a side to side anastomosis between the left ventral and left dorsal colon. It is highly likely the liquid diet facilitated the passage of intestinal contents through the anastomosis into the left dorsal colon after surgery. Over time, the intestine was able to progressively dilate, as the foal gradually transitioned to a solid diet. The limiting factor to the seamless passage of the ingesta would have been at the anastomosis. The surgeons elected to use an ILA 100 which provided a generous stoma of 10 cm. The 4.8 mm staples were of sufficient size to provide adequate security in an anastomosis performed across the taenial bands of the colon of a foal which, combined with free passage of the intestinal contents across the anastomosis, was likely to have provided adequate support and a sufficient seal at the anastomotic site. The anastomosis created blind ends in the left ventral and left dorsal colons aborally and orally, respectively, so these were resected to prevent impaction or blind loop syndrome (Leib 1987). It is suggested where innate, normal peristalsis is present, intestinal contents do not stagnate in blind loops (Justus *et al*. 1983). In one report of surgical treatment of atresia in the foal, the presence of a blind loop was not associated with blind loop syndrome (Biasutti *et al*. 2017). An alternative surgical technique that bypassed the hypoplastic left dorsal colon has been described in a foal with intestinal atresia (Biasutti *et al*. 2017).

While intestinal atresia is a rare condition in foals and generally considered to have a poor prognosis for survival (Nappert *et al*. 1992; Young *et al*. 1992), early recognition using appropriate diagnostic techniques and early surgical intervention offer an improved chance of survival if the affected segments are not too long and both blind ends are accessible and of sufficient diameter to achieve intestinal anastomosis (Prange 2013). The challenges of reaching a presurgical diagnosis in a timely fashion, in a real time scenario, are well highlighted in the case report presented in this edition of Equine Veterinary Education by Skov Hansen *et al*. (2021). Instituting appropriate supportive treatment prior to surgery, despite the delay in performing an exploratory laparotomy, contributed to the successful outcome. Surgical techniques for correction of intestinal atresia should anatomically and functionally aim to allow effective peristalsis and movement of ingesta across the anastomosis from the proximal to distal, without risk of obstruction, as the foal grows. The foal in this report was followed out to 20 months and had developed at a similar rate to its cohort suggesting these aims were achieved.

Authors' declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Ethical review not required for this clinical commentary.

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Case Report

Welfare and management of decreased visual capacities and pain in a pony suffering from equine recurrent uveitis: A clinical case

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Keywords: horse; animal welfare; pain; uveitis; blindness; medical training; medical observance; positive reinforcement

Summary

A 14-year old Gypsy Cob gelding (Rocky) penned in a 4 ha field, along with a group of five ponies, was found at nightfall, isolated, cantering in a circle and whinnying. Reactions to light and movement were abnormal: the pony did not react when the stimuli were applied to the right eye and showed small head avoidance on the left side. The owner also reported a new occurrence of abnormal surprise behaviour and hyper-reaction to stimuli. After complete ocular examination, ocular ultrasonography and intraocular pressure measurement, severe bilateral recurrent uveitis (ERU) was detected. The right eye presented with ocular globe degeneration and severe visual impairment. The left eye showed signs of chronic inflammation, but major anatomic structures were still preserved, with a minimal impairment of vision. ERU management was addressed both clinically and from a welfare point of view.

The pony's living conditions were adapted to meet his behavioural needs and let him express his natural behaviour. The pony was left in a field with social partners. He was able to display a normal time budget, spending most of his time grazing. The pony relied heavily on increased use of his remaining senses (hearing, touch, smell, taste). However, before he became completely blind, the owner decided to put him in a smaller paddock with hay and water, and one calm, carefully chosen social partner to live with, with a predictable daily routine.

During human–animal interactions, the owner took into account the pony's perceptive capacities (i.e. decreased visual capacities) and his temperament to adjust to them. The objective was to limit negative emotions (fear, anxiety, pain, frustration) and favour positive ones (joy). The owner warned the pony by calling him by his name whenever she started interacting or approaching him, to reduce unpredictability and suddenness, known to be a source of negative emotions. In addition, the ratio of positive to negative interactions was designed to largely favour 'rewarding' ones and to promote a positive animal representation of humans.

Drug administration required touching the pony's eye, which could be painful, causing avoidance behaviours. The owner used clicker training to train the pony to accept intervention on the eye, by eliciting positive emotions (**Fig 1**). Accepting ointment in the eye involved four steps. The owner gradually taught the pony to perform the desired four behaviours through shaping. She reported that after 5 days of ointment administration twice daily in each eye (i.e. 10 sessions per eye), the pony fully cooperated for drug administration in both eyes, thereby allowing medical observance.

This case is to our knowledge the first to include detailed welfare management strategies as a part of a more comprehensive medical approach to ERU.

Fig 1: Acceptance of ointment administration in the eye, after clicker training. First, the pony touches the owner's hand when given the verbal 'eye' command. Second, he stays still when the owner places the tips of her left-hand fingers on the upper and lower eyelid and opens the eye. Third, he stays still when the owner uses her right hand to put 4 mm of the ointment along the lower eyelid without touching the cornea.

Key points

- Disease management should be addressed by veterinarians both clinically and from a welfare point of view.
- The adaptation of physical and social environments together with positive relational practices decreases stress due to progressive loss of visual capacity by increasing predictability and controllability of the situation.
- Positive reinforcement and especially clicker training can facilitate clinical examination and treatment administration by eliciting positive emotions, leading to better treatment observance, and work comfort.

A. de Boyer des Roches and X. Peyrecave-Capo are equally contributing authors (co-first authors).

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Clinical Commentary

Hello darkness my old friend: Management of blind horses

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The case report by de Boyer des Roches *et al*. (2021) describes compassionate management of a Gypsy Cob pony gelding with bilateral equine recurrent uveitis (ERU). The pony presented blind in the right eye, with failing vision in the left. The report, which emphasises a holistic approach for care of visually impaired horses, provides an opportunity to discuss equine blindness and review training and management tactics that prioritise equine welfare, safety and comfort.

ERU and blindness

ERU is a syndrome of immune-mediated intraocular inflammatory disease that is the leading cause of blindness in horses worldwide. Disease can manifest with an insidious, progressive course or as acute inflammatory episodes that recur. Autoimmune inflammation that begins in the uvea soon affects other regions of the eye causing painful ocular damage and dysfunction that is often blinding (Gilger 2017). ERU can be unilateral or bilateral, affecting young as well as old horses. The Appaloosa breed has a genetic predisposition for ERU (Fritz *et al*. 2014; Rockwell *et al*. 2020) as do some draught and Warmblood breeds (**Fig 1**). The pathogenesis of ERU involves a complex cascade of immune-mediated events with leptospiral infection as the most common nongenetic trigger (Dwyer *et al*. 1995).

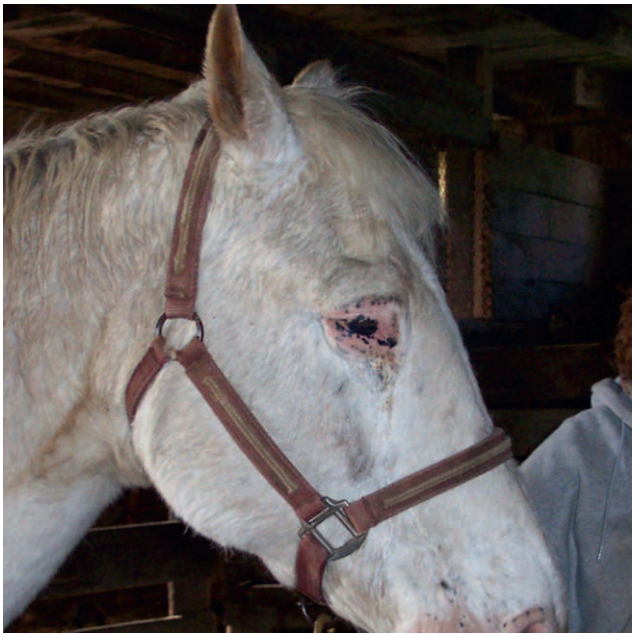

Fig 1: The Appaloosa breed has a genetic predisposition for ERU. Blepharospasm, blepharitis and epiphora are outward signs that often accompany intraocular inflammation.

Field data suggest that at least 2% of the world horse population suffers from ERU. Visual prognosis for ERU is guarded to poor: blindness is an eventual endpoint for over 50% of affected eyes even when horses receive comprehensive medical or surgical treatment (Dwyer *et al*. 1995; Dwyer 1998; Gerding 2016). Eyes with ERU lose sight for a variety of reasons including glaucoma, cataracts, retinal detachment or ciliary body dysfunction that progresses to phthisis bulbi.

Accounts of horses suffering from ERU trace back centuries to the Roman Empire. In the past, horses who went blind were frequently put down. Euthanasia remains an option at present, but in recent decades cultural attitudes towards blind animals have changed – owners often care for sightless horses for their natural lifespan. As a result, stables and farms in the developed world currently house thousands of blind horses.

The neuroscience of navigation in the dark

Injuries are surprisingly rare in blind horses; these animals easily locate food and water and respect fence perimeters. The navigational ability of blind horses is striking – they travel their 'home territory' with confidence, appearing to possess a 'mental map' of their environment.

Neuroscience research has investigated the remarkable physiology of navigation in the absence of visual input. Recent studies have discovered '*neuroplasticity*' in human brains: if light signal processing ceases, the neuronal circuitry of the large visual cortex 'rewires' to integrate other stimuli, particularly auditory and tactile signals (Burton 2003; Liu *et al*. 2007). This process may explain why blind horses seem strongly reliant on their senses of touch and hearing: brain circuitry originally dedicated to visual input may be reallocated to receive and process signals from these senses, aiding navigation. Another system in the CNS that may aid navigation is '*path integration*'. This process involves a complex cellular network in the brain that functions as an 'internal GPS'. As an animal or person moves through space, various classes of cells in the hippocampus and parahippocampus fire in a grid-like pattern unique to the space crossed, creating a three-dimensional construct of electrical activity (Sargolini *et al*. 2006; Epstein *et al*. 2007). Though this network normally is activated by visual stimuli, path integration occurs in blind human subjects in the *absence* of visual stimuli, possibly though tactile signals routed through the visual cortex (Kupers *et al*. 2010; Ricciardi *et al*. 2014).

Management of blind horses

Whatever the physiologic adaptations are that allow blind horses to navigate well independently, sightless horses also have daily interactions with people. Handlers of blind horses must provide a safe, predictable, low-stress environment.

Training tactics must promote co-operation during handling and guide the horse in navigation of novel environments.

The pony in the report was blind from ERU in the right eye with failing sight in the left. After sustaining an injury in a pasture shared with a small herd, he was moved to a smaller pen with few physical hazards, and a quiet gelding was introduced as a companion. Removal from the herd and substitution of a single 'buddy' horse are recommended for horses with diminished or absent sight. The sighted 'buddy' horse, whose halter may be fitted with a bell, serves as a 'seeing eye' guide for the blind horse, and a strong social bond typically develops (Dwyer 2017a) (**Fig 2**). Housing a blind horse in a secure, well-fenced environment with a gentle companion reduces the chance of injury, optimises access to feed and eliminates the risks of herd dynamics.

The owner also trained the pony to respond to multiple verbal guidance commands such as 'Stop', 'Go', 'Stay' and 'Step up'. Conditioning blind horses to obey such commands has obvious merit in directing safe behaviour and aiding navigation of obstacles or unfamiliar territory. Consistent human handling that centres on 'talking and touching' has been noted to reduce anxiety and fear; a predictable routine instils trust and favours improved learning (Dwyer 2017a).

Fig 2: a) The chestnut mare has recently become bilaterally blind from glaucoma. She is turned out in a securely fenced pasture with a single sighted 'buddy'. b) A bell attached to the buddy horse's halter provides audible guidance that helps the blind mare navigate.

Lives blind horses lead

Many blind horses with tractable dispositions and appropriate training are used as trail horses, as was the pony in the report. Safe mounted activity in a sighted horse depends on a suitable temperament, careful training and regular outings; similar basics are essential for riding any blind horse. While there are obvious safety concerns that should be raised if owners choose to ride blind horses, reported problems are rare. A few blind horses have had remarkable success competing in dressage, reining or other events that do not involve negotiation of obstacles (Dwyer 2017a).

Blind horses that are not used for riding fulfil a range of roles. Many are kept as 'pasture pets' and become treasured family members. Ground training may include agility exercises and instruction in unmounted 'tricks'. Some gentle blind horses provide settling companionship for sighted horses with flighty temperaments. Mares whose blindness is not associated with genetic risk may be used for breeding; many have raised multiple sighted foals.

There is a large population of blind horses, donkeys and mules in developing countries. Regional economies in the third world rely on working equids to perform farm labour, transport people and haul loads of goods; many animals continue to perform this essential work after one or both eyes become(s) blind (Dwyer 2017b).

Positive reinforcement training for working around the eyes

ERU requires frequent topical therapy for reduction of intraocular inflammation (McMullen 2017), but ocular pain often incites aversive behaviour, making treatment difficult and ineffective. Positive reinforcement was used to train the pony to accept daily application of eye ointment.

Horse training has historically focused on negative reinforcement, or the removal of an adverse stimulus when a desired behaviour is achieved. An example is a handler pulling on a lead rope to load a horse in a trailer, then releasing the rope tension as soon as the horse steps up on the ramp. Positive reinforcement (PR) is a newer training method that involves the addition of a pleasant stimulus (reinforcement) as a reward when a desired behaviour is displayed. An example of PR is giving the horse a food treat when it steps up on the ramp to enter a trailer (Hendriksen *et al*. 2011). PR training grew out of mammalian behaviour

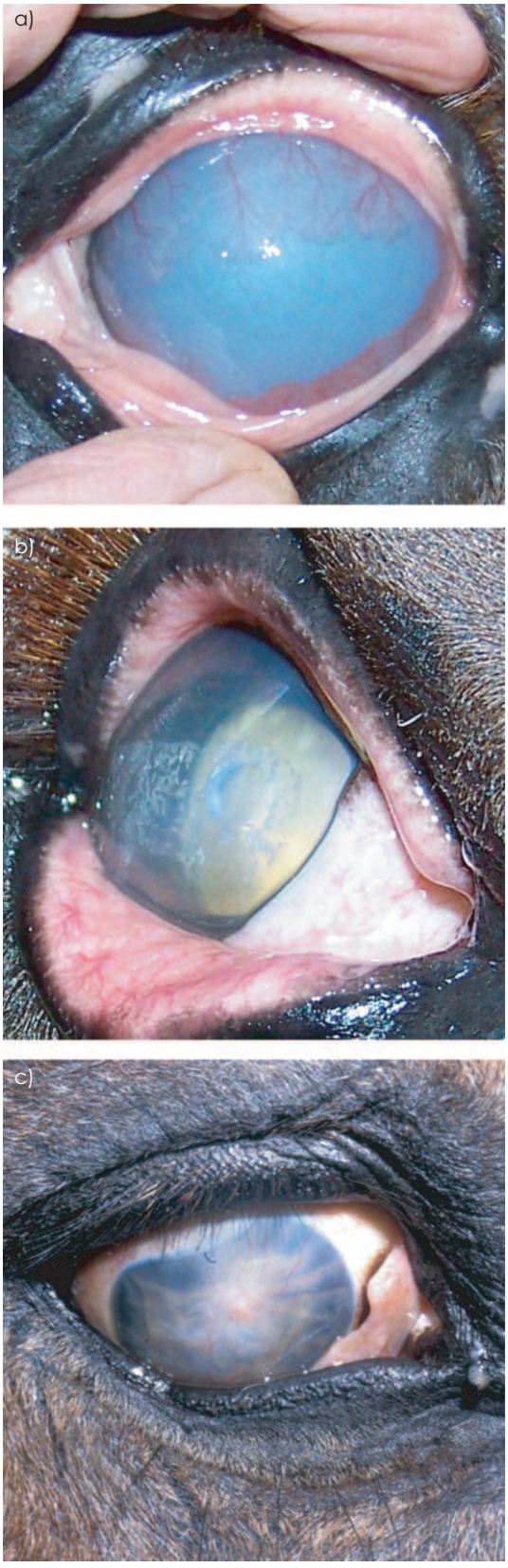

Fig 3: Examples of blind ERU eyes that were enucleated to abolish chronic pain. Each horse's attitude improved immediately. a) Globe affected with glaucoma and keratitis. b) Globe affected with calcific keratitis, chronic ulcerative keratitis and mature cataract. c) Phthsical globe that has atrophied due to iridocyclitis.

research and has been widely adopted by trainers, stable managers and horse owners.

PR-based behaviour modification training involves the sequential application of two paired stimuli: a primary reinforcement and a secondary reinforcement. The primary reinforcement (P-RF) is a motivating stimulus that fulfils a

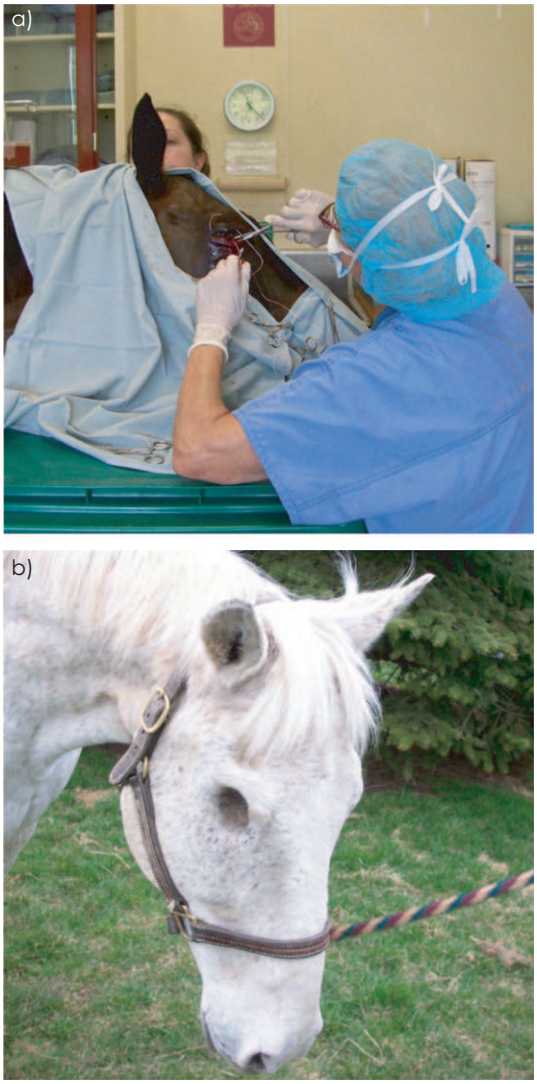

Fig 4: a) Standing enucleation surgery of the right globe. The eyelid margins are being sutured together for a transpalpebral approach. b) Appearance of a horse who has undergone enucleation of the right globe.

biologic need—e.g. feeding a tasty morsel of food like a carrot slice. The secondary reinforcement (S-RF) is an independent, consistent stimulus that the horse learns to associate with the primary reinforcement. The S-RF may be a sharp noise made with the tongue or a mechanical 'clicker', or a verbal cue delivered in a constant tone and pitch, or a tactile stimulus like a touch delivered to the chest or withers. The S-RF stimulus is given in quick succession with the P-RF when the desired action occurs (Heleski *et al*. 2008). Studies have shown that horses learn to associate the S-RF with the primary biologic need of the P-RF in as few as 10 repetitions (McDonnell, 2000). At that point, the P-RF (which if used constantly might result in undesirable behaviour like nipping) can be dropped, as the trained horse will display the desired behaviour in response to *just* the S-RF. The association can be maintained if the handler repeats the P-RF (adds a carrot treat to the click of the S-RF) about every 10th time the sequence occurs (McDonnell, 2000).

In the case report, delivery of topical ophthalmic ointment required the pony to first allow the handler to touch his head, then part his eyelids, then apply a strip of ointment and finally close and massage the lids. Consistent positive reinforcement at each of these steps using the S-RF of a crisp 'tongue click', paired with the P-RF of a carrot treat, resulted in predictable cooperation after the training was repeated 10 times (two treatments per day over 5 days). As a bonus of 'clicker training', the pony was compliant for veterinary ocular examinations involving eyelid manipulation and did not need sedation for ultrasonography or tonometry.

PR training can be implemented for any condition requiring topical ophthalmic therapy, including corneal ulcers. PR can also train horses to behave for interventions like injections, clipping, picking up feet, rectal thermometry or opening the mouth.

Treatment of ocular pain with enucleation

Onset of blindness does not abolish ocular inflammation; many manifestations of end-stage ERU, including glaucoma, calcific keratitis, iridocyclitis and phthisis bulbi, are characterised by chronic, debilitating pain. Severe pain is also present in many blinding conditions unrelated to ERU such as endophthalmitis, keratomalacia, stromal abscesses, bullous keratopathy and penetrating ocular trauma. The issue of persistent pain in any blind eye is a serious equine welfare concern.

People with phthisical blind eyes often report ocular pain (Doyle *et al*. 2018); enucleation paired with an orbital prosthesis may be performed if pain is intractable (Custer 2000). Owners of 72 dogs who underwent bilateral enucleation were surveyed about their dog's post-operative quality of life, and 96% reported positive benefits including increased activity level and playfulness and lack of aversion to facial/ocular palpation (Hamzianpour *et al*. 2019). A survey of 34 horses who were unilaterally enucleated for a variety of reasons showed that complications were rare and the majority of horses returned to their previous occupation (Utter *et al*. 2010). Numerous horses that have undergone unilateral or bilateral enucleation in the author's practice have shown a marked improvement in temperament and quality of life, often becoming much easier to handle. Enucleation surgery is strongly recommended for blind eyes that are chronically painful, and for blind eyes that suffer recurrent keratitis or other problems where treatment is only palliative (**Fig 3**).

Enucleation, which in decades past was performed under general anaesthesia, is now commonly done as a standing procedure in awake, sedated horses. Standing enucleation is a relatively simple surgery that can be done using local anaesthesia coupled with a retrobulbar block (Pollock *et al*. 2008; Townsend 2013; LaBelle 2013). Surgery is performed in stocks or a well-lit stall; preparation and operating time ranges from 60 to 90 min (**Fig 4**). Recovery is typically rapid, and complications are rare: of 57 standing enucleations performed in the author's practice over a 6-year period (2009–2015), just three horses (5%) developed post-operative infections, all of which resolved with treatment (A.E. Dwyer [2020] Unpublished data from 2009 to 2015 medical records of Genesee Valley Equine Clinic, Scottsville, NY, USA).

Owner education

Blindness is a frequent endpoint for horses who suffer ERU; associated ocular pain may require lifelong topical medication or enucleation of a blind globe. Veterinarians managing horses with ERU, or any disease that is blinding, must prioritise owner education, as management that optimises patient welfare depends on multiple interventions at the home stable. The website www.blindhorses.org (accessed 17 August 2020) is source of excellent information that contains practical articles on blind horse management, as well as scientific content on ERU and other equine eye diseases. The YouTube video series 'Don't break your vet!' produced by BEVA provides online tutorials for positive reinforcement training: https://youtu.be/JnwrDMsQGx0 (introductory link leading to the online tutorial series, accessed 17 August 2020).

Managing a blind horse has challenges, but is embraced by thousands of horse owners worldwide. In return, owners that provide for the special needs of a blind animal find emotional satisfaction summed up in this quote:

Kindness is the language which the deaf can hear and the blind can see. Mark Twain

Author's declaration of interests

No conflicts of interest have been declared.

Ethical animal research

Not applicable to this clinical commentary.

Source of funding

No source of funding.

Internet resources

British Equine Veterinary Association. "Don't break your vet!" Series of YouTube videos:

Introduction: https://youtu.be/JnwrDMsQGx0
Clicker Training:
https://youtu.be/n6V35th1Mbo

Learning to stand still:
https://youtu.be/kp5nFwziBkE
Happy Heads:
https://youtu.be/34e53LQCyIM
Website with additional information about blind horses
https://blindhorses.org/resources/

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Original Article

Sustainability in equine veterinary practice: A survey of opinions and practices amongst veterinary teams in the United Kingdom

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Keywords: horse; sustainability; climate change; veterinary practice

Summary

Background
Veterinarians occupy a unique position at the animal–human–environment interface and could play a crucial role in mitigating climate change and other environmental impacts of human activities.

Objectives
To survey the opinions of equine veterinary teams in the UK regarding the importance of sustainability issues and current practices employed to promote sustainability.

Study design
Online survey.

Methods
The survey was distributed through various email veterinary listservs and social media sites, and was open to equine veterinary surgeons, veterinary nurses, veterinary students and practice administrators/managers.

Results
A total of 374 responses were received. 77% of respondents considered sustainability issues to be extremely important or very important, but only 13% felt knowledgeable/well-informed about practical ways of promoting sustainability in equine veterinary practice. 56% of respondents stated that their organisations/practices had not introduced sustainability protocols. Over 50% of respondents considered that their organisations were dealing well with the issues of antimicrobial stewardship, anthelmintic stewardship and drug disposal, but less than 25% considered that their organisations were dealing well with fossil fuels, travel, disposable materials, responsible paper sourcing, water-saving and communicating sustainability issues.

Main limitations
Potential selection bias and response bias.

Conclusions
Sustainability issues are considered important by the majority of equine veterinary practice teams in the UK, but there is a widespread lack of knowledge about practical ways of promoting sustainability.

Clinical relevance

- There is a need for organisations to develop policies to promote sustainability in equine veterinary practice.
- There appears to be a mismatch between the opinions of equine veterinary teams regarding the importance of sustainability, and the practical implementation of measures to promote sustainability.
- Topics that require more consideration and action include reliance on fossil fuels, travel, disposable materials, responsible paper sourcing, water-saving and communicating sustainability issues.

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Original Article

Evaluation of cervical radiographs in Dutch Warmblood horses, using a novel radiographic grading system for the cervical articular process joints

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Keywords: horse; radiography; cervical; grading; system

Summary

Clinical and radiographic examination of the cervical spine has been of increasing interest in the prepurchase examination and clinical work-up conducted for horses. The objective of this study was to describe a grading system useful for evaluating all the cervical articular process joints (cAPJs). Additionally, the findings of the cervical radiographs (occiput, cAPJ and intercentral joint space grading, intra- and intervertebral sagittal ratios, and intervertebral disc width measurements) were reported, and their association with clinical complaints in a large group of Dutch Warmblood horses (n = 598) were investigated. Significant associations were found between cAPJ radiographic grades and clinical complaints using the chi-squared test (C2-3 [P = 0.01], C5-6 [P = 0.006], C6-7 [P < 0.001], and C7-T1 [P = 0.02]). Higher occiput grades were significantly associated with clinical complaints (chi-squared test, P = 0.005). A large variability was found for intra- and intervertebral ratios and minimum intercentral joint space in the control group, but no significant association between intercentral joint space and clinical complaints was observed using the Kruskal–Wallis test followed by post hoc testing with the Wilcoxon rank sum test with a Bonferroni correction. The main limitations of this study were that only information regarding localisation was used for the statistical analyses, without any other details of the clinical complaints. Furthermore, clinical records were retrospectively reviewed, and a bias towards cervical findings in the clinical data recordings should be considered. It was concluded that knowledge of the distribution of the radiographic findings evaluated in this study and their associated clinical relevance can be useful in reaching a science-based diagnosis in daily practice.

Introduction

There is an increasing interest in clinical and radiographic examinations of the cervical spine of horses, both for prepurchase examinations and normal clinical work-up. While cervical examinations are sometimes necessary to evaluate trauma, more often there are performance-related issues and/or complaints of lameness. In the diagnostic process, the first step is a clinical examination. Clinical findings are diverse, including reduced range of motion, stiffness, unwillingness to work on the bit and lameness, wherein the source of pain cannot be localised to the limb (Van Biervliet 2007; Dyson 2011).

The next step is a thorough radiographic examination. Radiographic examination of the cervical spine contains a series of laterolateral projections from the occiput to the first thoracic vertebrae (T1). In case of abnormalities detected on these radiographs, additional lateral oblique views can provide additional information (Withers *et al*. 2009). Normal radiographic anatomy, anatomical variations and abnormalities related to the cervical spine have been documented previously (Van Biervliet 2007; Butler *et al*. 2008; Hahn *et al*. 2008; Dyson 2011; Scrivani *et al*. 2011; Santinelli *et al*. 2016). However, these studies mainly focused on the caudal cervical spine or described specific abnormalities. To our knowledge, apart from a system using enlargement features to grade the cervical (C) 5-6 and C6-7 articular process joints, no radiological grading system has been described that can be effectively used for all cervical articular process joints (cAPJs) (Down and Henson 2009).

In this article, we first aimed to describe a grading system for cAPJs that combines various radiographic findings, such as periarticular enlargement, delineation and asymmetry of the enlargement, and presence of radiolucencies, fragments, fractures and/or congenital abnormalities. Second, this study aimed to describe the findings of the cervical radiographs and investigate their association with clinical complaints in a large sample of Dutch Warmblood horses.

Materials and methods

Complete cervical radiographic examinations of Dutch Warmblood horses, performed at the equine clinic in Bodegraven between June 2013 and January 2018, were reviewed. Cases were retrieved from the picture archiving and communication system (PACS) and included in the retrospective analysis if the study was complete (i.e. from the occiput to T1) and image quality was acceptable for interpretation. This analysis included 664 complete cervical radiographic examinations. Between June 2013 and July 2016, images were acquired using a computed radiographic system (AGFA CR75.0[1]), whereas a direct digital radiographic system (AGFA DX-D 45C[1]) was used after July 2016. Both systems were used in combination with a Bucky grid (ratio 12:1). Sedated horses stood square and freely with the neck

in a neutral (horizontal) posture. The head was minimally supported by a handler, holding it in a neutral and straightforward position perpendicular to the x-ray beam. For the projection of the occiput, the ears were taped forward to avoid superimposition of the auricular cartilages on the occiput. The Bucky system touched the horse's right side with a film-focus distance of 100 cm. Consecutive laterolateral projections were performed with enough overlap to ensure that the complete cervical area from the occiput to the cAPJs between C7-T1 at least was recorded with limited radiographic distortion artefacts due to beam divergence. Practically, all horses underwent 4–8 left lateral-right lateral radiographic projections according to their size.

All images were viewed cranial to the left and dorsal to the top using OsiriX DICOM viewing software version 8.0.1[2]. If included in more than one projection, the cAPJs were graded on the projection providing least craniocaudal and laterolateral obliquity.

Each individual cAPJ was graded according to a radiographic grading system containing seven grades (grades 0–6), as described in **Fig 1**. This grading system combines radiographic signs associated with abnormal cAPJs, such as abnormal size, periarticular modelling, asymmetry, radiolucencies, increased opacity and fragmentation (**Figs 1** and **2**) (Van Biervliet 2007; Butler *et al*. 2008; Down and Henson 2009; Dyson 2011; Kristoffersen *et al*. 2014; DeRouen *et al*. 2016). The occiput itself was graded according to the presence and severity of modelling (grade 0: no modelling; grade 1: irregular delineation of the occiput; grade 2: craniocaudal extension is less than the dorsoventral height of the occiput; grade 3: craniocaudal extension is similar to the dorsoventral height of the occiput; and grade 4: fragmented modelling) (**Fig 3**). The ventral lamina of C6 was graded as present, asymmetrical absence or symmetrical absence. Spinous processes of C7 and T1 were graded by shape and appearance as previously described by Santinelli *et al*. (2016) (C7: absent, sharp triangular, rounded triangular, or spur-like; and T1: short and squat, or high and pronounced). Finally, the intercentral joint space appearance was graded for each joint from C2-3 to C7-T1 as normal, incongruent (ventrally narrower as compared to dorsal), mineralised (mineralisation most often detected dorsally in the intercentral joint space), subluxation (between two adjacent vertebrae) or a combination of these findings.

To determine suitability and agreement of the interpretation of the suggested grading system, one of the authors and two experienced clinicians reviewed 15 randomly selected cases and discussed the results to reach interobserver consensus. To determine intraobserver repeatability, one of the authors (C.C.) reviewed 10 randomly selected cases 10 times over a period of 30 days.

All studies included in the analysis were reviewed without knowledge of the clinical status of the horses by one experienced analyst (C.C.).

Aside from the categorical evaluation system, several measurements were made (**Fig 4**). First, the minimum intercentral joint space widths were measured.

Second, measurements were performed to calculate the sagittal ratio of the vertebral foramen for each vertebra from C3 to T1, and the intervertebral sagittal ratio for each intervertebral distance from C2-3 to C7-T1. The sagittal and intervertebral sagittal ratios were calculated by dividing the sagittal or intervertebral diameter by the dorsoventral height of the corresponding vertebrae (Butler *et al*. 2008; Hahn *et al*. 2008; Scrivani *et al*. 2011). The intra- and intervertebral ratios were compared with the reported cut-off value of 0.485 for the minimum sagittal diameter, as described by Hahn *et al*. (2008).

In the second phase, the clinical records of the cases included were reviewed. Reasons for admission to the clinic and final diagnosis were reviewed to distinguish between cervical-related cases and noncervical-related cases (i.e. prepurchase, noncervical-related lameness, and thoracolumbar-related cases). Cases were included in the cervical group if cervical-related disorders, such as reduced range of motion, stiffness, unwillingness to work on the bit and lameness, originating from the cervical region were recorded during clinical examination. A standard clinical examination included an evaluation of the cervical range of motion (active and passive), stiffness and localisation of pain by palpation. All clinical examinations were performed by one clinician out of three clinicians with at least 15 years of experience in equine orthopaedic examinations. Cases were included in the noncervical group if the clinical examination records showed no record of cervical-related disorders. Clinical examination records revealed that in most cases, the anamnesis and clinical examination findings (conformation, shape, posture, palpation and manual manipulation findings, and observation findings on the lunge and/or ridden) led to the clinical conclusion and localisation of the cervical-related complaints. The amount of combinations of symptoms described in the clinical records did not allow cases to be divided into a surveyable number of groups for statistical analysis. Therefore, the cervical-related cases were divided into three groups based on the origin of the complaints, that is in the cranial, middle or caudal portion of the cervical region. Cases were excluded from the statistical analyses if clinical records did not indicate clear assignment to the control group or to one of the clinical groups (e.g. if cervical-related complaints were recorded without mentioning the localisation of the complaints).

Data analysis

All statistical analyses were conducted using software program R (version 3.1.2c)[3]. First, for categorical variables, the distribution per clinical category was reported, and continuous variables were presented as median and range. Second, the association with clinical findings (case–control) was investigated for both the categorical and continuous variables. For the categorical variables, a chi-squared test was used (P-value obtained with Monte Carlo simulation, 100,000 replicates), while the Kruskal–Wallis test was used for continuous variables followed by post hoc testing with the Wilcoxon rank sum test with a Bonferroni correction. Throughout the analyses, significance was set at $P \leq 0.05$.

To evaluate intraobserver agreement, kappa (*k*) was calculated for all pairwise combinations from the 10 readings, and the average *k*-value was calculated. The obtained *k*-values were classified in a six-category classification system, as described by Landis and Koch (1977).

Finally, based on the group of control horses, reference intervals were calculated according to the guidelines by the American Society for Veterinary Clinical pathology, using a nonparametric approach (Friedrichs *et al*. 2012).

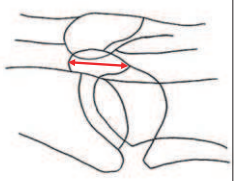
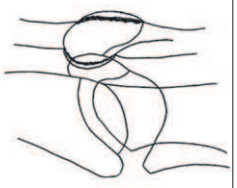
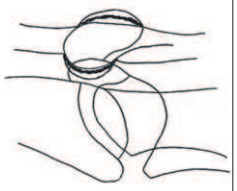
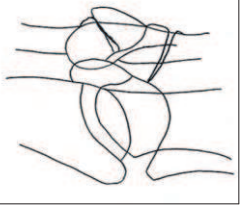
cAPJs Grade	Description	Diagram
0	Normal in size with smooth margins of the cAPJs. No radiolucencies and/or increased opacities are present, not asymmetrically enlarged. (Double arrow on the diagram indicates the 50% border of the intervertebral foramen to distinguish between mild and moderate enlargement)	
1	Mildly enlarged (up to 50% obliteration of the intervertebral foramen by the ventral margin of the cAPJs and/or a similar amount of modelling on the dorsal margin of the cAPJ) with smooth margins of the cAPJs 'or' normal in size with irregular margins of the cAPJs. No radiolucencies and/or increased opacities are present, not asymmetrically enlarged	
2	Mildly enlarged with irregular margins of the cAPJs 'or' moderately enlarged (up to 100% obliteration of the intervertebral foramen by the ventral margin of the cAPJs and/or a similar amount of modelling on the dorsal margin of the cAPJs) and smooth margins of the cAPJs. No radiolucencies and/or increased opacities are present, not asymmetrically enlarged	
3	Moderately enlarged with irregular margins of the cAPJs 'or' mildly enlarged with irregular margins and small radiolucencies present without surrounding increased opacitie present 'and/or' asymmetrically enlarged.	
4	Moderate to severely enlarged (100% obliteration of the intervertebral foramen by the ventral margin of the cAPJs with buttress formation and/or a similar amount of modelling on the dorsal margin of the cAPJs) with irregular margins of the cAPJs 'and/or' small radiolucencies surrounded by increased opacitie 'or' large radiolucencies without surrounding increased opacitie present 'and/or' asymmetrically enlarged.	
5	Severely enlarged, irregular delineated 'and/or' large radiolucencies surrounded by increased opacities 'and/or' fragmentation present 'and/or' asymmetrically enlarged	
6	Fractures 'or' severe congenital abnormalities	

Fig 1: Descriptions and diagrams of the different cervical articular process joints grades.

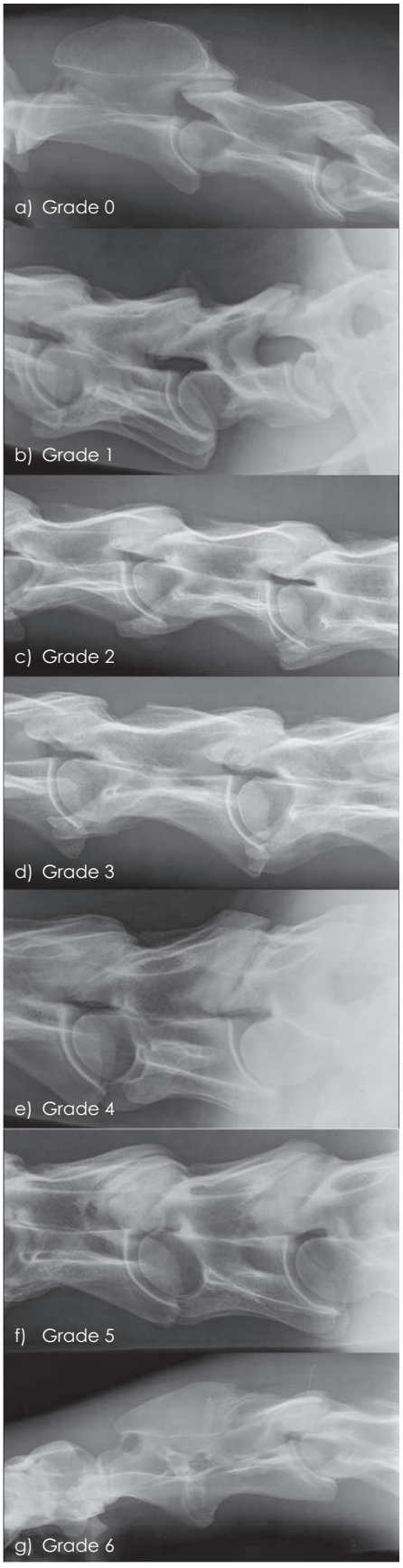


Fig 2: Radiographic examples of the different cervical articular process joints (cAPJ) grades. a) Grade 0 C2-3 APJs are normal in size and smooth delineated. b) Grade 1 C6-7 APJs are normal in size but are a mild irregularly delineated. c) Grade 2 both C3-4 and C4-5 APJs are moderately enlarged and smoothly delineated. d) Grade 3 C5-6 APJs are moderately enlarged and irregularly delineated. e) Grade 4 C6-7 APJs are moderate to severely, asymmetrically enlarged, irregularly delineated with some smaller radiolucencies surrounded by increased opacities. f) Grade 5 C5-6 and C6-7 APJs are severely, asymmetrically enlarged and irregularly delineated. G- Grade 6 C2 and C3 are fused representing a severe congenital abnormality.

Results

In total, 664 cervical radiographic studies of Dutch Warmblood horses were reviewed in the first phase of the study. In the second phase, 66 cases were excluded from further statistical analyses based on the clinical records. Consequently, statistical analysis was performed for 598 cases. The median age of the 598 horses included was 6 years (range, 1–23 years). There were 178 horses aged less than 5 years, 332 horses between 5 and 10 years, 71 horses between 11–15 years, and 17 horses older than 15 years. There were 352 geldings, 208 mares and 38 stallions. The control group (n = 372) consisted of 199 clinically sound horses presented for passing a prepurchase examination, 100 horses with a limb-related lameness and 73 horses with thoracolumbar-related complaints. The clinical group (n = 226) comprised of 31 horses with complaints related to the cranial half of the cervical region, 3 horses with specific complaints of the midcervical region and 192 horses with complaints of the caudal half of the cervical region.

The distribution of radiographic grades of cAPJs is presented in **Table 1**.

Overall, a significant association ($P = 0.01$) was found between radiographic grades of the C2-3 cAPJs and the clinical group. In fact, the grades seemed to be higher in the group with cervical-related complaints in the cranial half of the cervical region as compared to the other groups. A similar association between higher radiographic grades for the cAPJs in the clinical group was found for the radiographic grades of C5-6, C6-7 and C7-T1 ($P < 0.01$, $P < 0.001$ and $P = 0.02$, respectively). In this case, higher radiographic grades were found more often in the clinical group with complaints in the caudal half of the cervical region as compared to the other groups. No significant differences in the distribution of the radiographic grades between groups were found for the C3-4 ($P = 0.10$) and C4-5 ($P = 0.07$) cAPJs.

Kappa statistics revealed almost perfect intraobserver repeatability for the grading of cAPJs using the proposed grading system: C2-3, $k = 0.90$; C3-4, $k = 0.93$; C4-5, $k = 1$; C5-6, $k = 0.97$; C6-7, $k = 1$; and C7-T1, $k = 0.91$.

The distribution of radiographic grades of the occiput is presented in **Table 2**.

In one case, the ligamentum nuchae was mineralised over a longer length. A significant association ($P = 0.005$) was found between the radiographic grades and the clinical group with complaints in the cranial half of the cervical region.

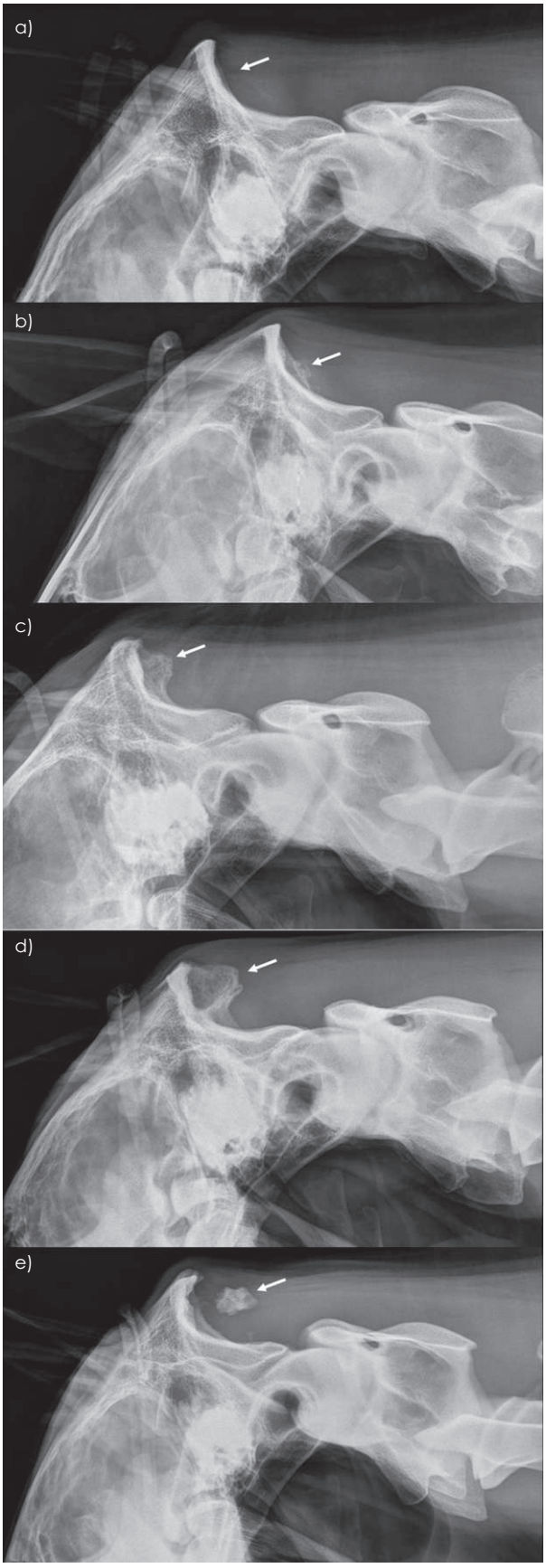


Fig 3: Radiographic examples of severity of modelling at the level of the occiput. a) no modelling (grade 0). b) mild modelling (irregular delineation of the occiput – arrow – grade 1). c) moderate modelling (craniocaudal extension is less than the dorsoventral height of the occiput – arrow – grade 2). d) severe modelling (craniocaudal extension is similar to the dorsoventral height of the occiput – arrow – grade 3). e) fragmented modelling (arrow – grade 4)

The ventral laminae of C6 were symmetrically present in 430 (72%) horses, while 92 (16%) horses showed an asymmetric absence of the ventral laminae, and 76 (12%) horses had no ventral laminae on C6. Anatomy of the ventral laminae showed no significant differences in the distribution between the clinical and control groups ($P > 0.9$). The absence or presence of only a small spur-like spinous process on C7 was associated with a short and squat T1 spinous process, whereas a more pronounced sharp triangular or rounded triangular spinous process on C7 was associated with a high and pronounced T1 spinous process ($P < 0.001$). However, no significant association was found between the clinical and control groups ($P = 0.43$) with respect to the anatomical variation of the ventral laminae of C6 and spinous processes of C7 and T1.

Next, the intra- and intervertebral ratios and minimum intercentral joint space width measurements were compared. None of these variables showed a significant association with the clinical group.

Of the 6640 measurements performed, 164 intra- and 11 intervertebral ratios were below the cut-off value of 0.485 for the minimum sagittal diameter, as described by Hahn *et al*. (2008). In total, 88 cases showed single (n = 43) or multiple (n = 45) measurements below the cut-off value. Seven of

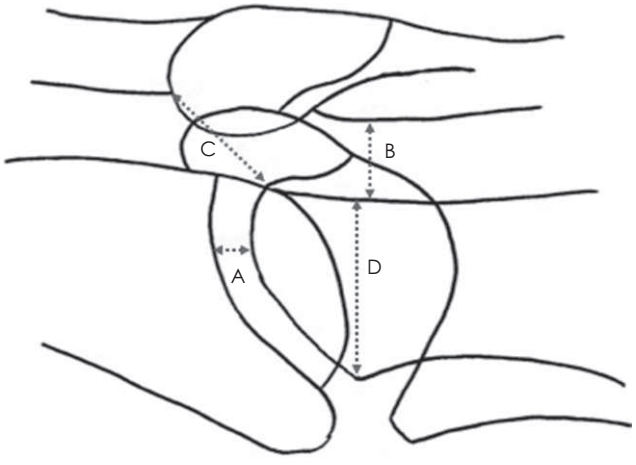


Fig 4: Measurements: The intercentral joint space a) was measured perpendicular to the joint space at the narrowest portion of the joint. The minimum sagittal diameter b) was measured perpendicular to the ventral aspect of the vertebral canal. The intervertebral diameter c) was measured as the distance between the ventrocaudal aspect of the lamina of the cranial vertebra to the craniproximal aspect of the physis of the vertebral body of the caudal vertebra. The dorsoventral height d) was measured at the level of the widest part of the cranial aspect of the vertebral head of the caudal vertebra.

TABLE 1: Distribution of radiographic grade per cervical articular process joints (cAPJs), amount of cases included in each grade per cAPJs and level of significance of a chi-squared test obtained with Monte Carlo simulation

cAPJs P-value	Grade Group	0	1	2	3	4	5	6
C2-3	Cranial	0	11	12	2	4	1	1
P = 0.01	Mid	0	2	1	0	0	0	0
	Caudal	8	90	71	19	4	0	0
	Control	18	205	118	28	3	0	0
C3-4	Cranial	2	11	13	3	2	0	0
P = 0.10	Mid	0	1	2	0	0	0	0
	Caudal	5	84	81	21	1	0	0
	Control	23	189	128	28	4	0	0
C4-5	Cranial	1	9	8	12	1	0	0
P = 0.07	Mid	0	0	1	2	0	0	0
	Caudal	2	54	74	52	8	2	0
	Control	10	138	148	65	11	0	0
C5-6	Cranial	0	5	7	15	4	0	0
P = 0.006	Mid	0	0	1	1	1	0	0
	Caudal	1	25	65	51	42	8	0
	Control	4	70	180	89	27	2	0
C6-7	Cranial	0	1	6	14	9	1	0
P = 4e-05	Mid	0	1	0	2	0	0	0
	Caudal	0	4	14	46	85	40	3
	Control	0	25	110	152	75	10	0
C7-T1	Cranial	2	16	8	5	0	0	0
P = 0.02	Mid	0	1	2	0	0	0	0
	Caudal	4	52	73	48	7	4	4
	Control	21	188	113	48	2	0	0

TABLE 2: Distribution of radiographic grade of the occiput, amount of cases included in each grade and level of significance of a chi-squared test obtained with Monte Carlo simulation

Occiput P-value	Grade Group	0	1	2	3	4	5
P = 0.01	Cranial	5	5	3	5	13	0
	Mid	0	3	0	0	0	0
	Caudal	26	90	47	17	12	0
	Control	42	194	98	17	20	1

these cases were confirmed to be neurologically abnormal based on the Magnetic Motor Evoked Potential test (Nollet *et al*. 2002). The clinical records of the other cases showed no indication for performing neurological evaluation. These cases presented cervical diagnosis (n = 31), orthopaedic diagnosis (n = 8), back-related diagnosis (n = 5) or prepurchase examination (n = 37).

Finally, the reference ranges were calculated based on the 372 control horses included in the study for the intra- and intervertebral ratios and minimum intercentral joint space widths (**Figs 5** and **6**).

Discussion

This study aimed to describe a radiographic grading system useful for all cAPJs in horses. The grading system allowed for consistent image interpretation. Furthermore, it was clear that scores based on the grading system were significantly associated with the clinical complaints for several cAPJs. The cAPJs were higher graded in the same region of the record of the clinical complaints. A review of the results showed between grade 3 and 4 cAPJs, a steep increase in clinical cases compared to control cases.

In this study, 38% of the included cases showed clinical complaints similar to that of a study population from a previous report (Down and Henson 2009). Clinical examination allowed distinction between the clinical complaints originating in the cranial (14%) and caudal (85%) halves of the cervical region. Anecdotal data describing specific abnormalities and clinical complaints related to the caudal half of the cervical spine (Butler *et al*. 2008; Down and Henson 2009) were in accordance with the distribution found in this study.

The results showed a significant association between the radiographic grade and clinical signs for all cAPJs, except the midcervical region of C3-4 and C4-5. This was in contrast with a previous report showing no association between radiographic grade and clinical signs (Down and Henson 2009). This previously described grading system (Down and Henson 2009) focused only on periarticular enlargement and was suitable only for caudal cAPJs. Although periarticular enlargement is recognised as an important radiographic sign of arthropathy of cAPJs, it should not be considered the only radiographic sign for the evaluation of cAPJs. Given the

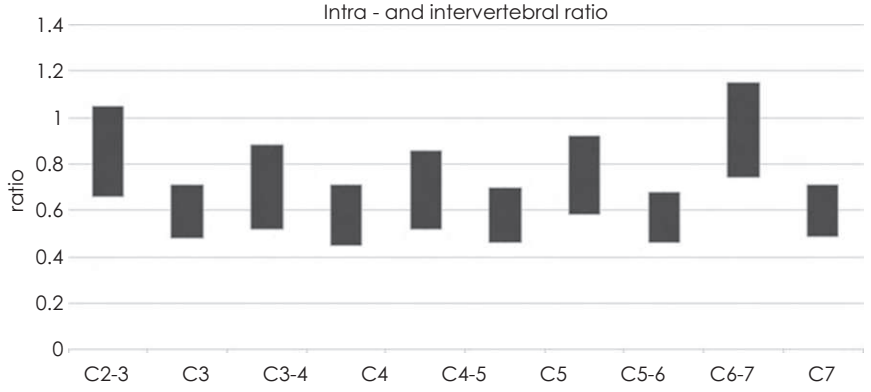


Fig 5: Reference intervals minimum and maximum values for the intra- and intervertebral ratios of and between cervical vertebrae calculated using a nonparametric approach in the control group.

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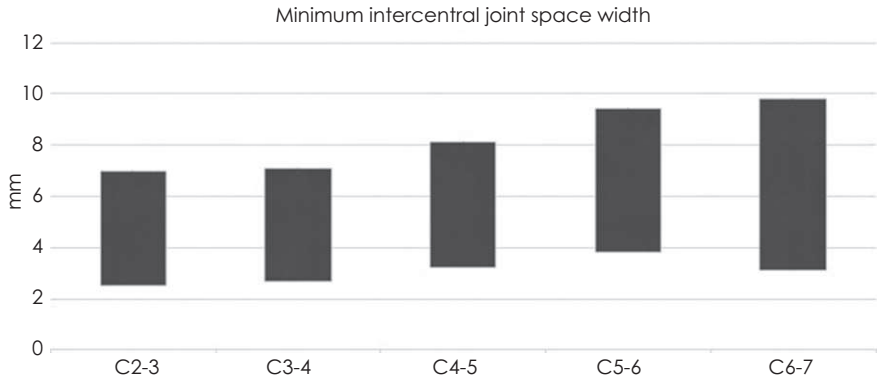

Fig 6: Reference intervals minimum and maximum values calculated for minimum intercentral joint space width between cervical vertebrae using a nonparametric approach in the control group.

results from the evaluation of additional typical radiographic signs (Butler *et al*. 2008; Dyson 2011) in combination with periarticular enlargement, the proposed grading system allowed for a more comprehensive sliding differentiation between the grades. This possibly explained the ability to show an association between radiographic grade and clinical signs. It should also be emphasised that the location influences the direction of the enlargement. Contrary to the caudal cervical vertebrae, which are more vertically oriented joints and where enlargement is both dorsal and ventral, the cranial vertebrae are more horizontally oriented joints that mainly show ventral enlargement.

As mentioned, cAPJ radiographic grades were associated with clinical presentation, except in the midcervical region. The missing association with the midcervical region could be attributed to the very small group of clinically affected horses (1%) with specific midcervical complaints. Furthermore, our experience has revealed that clinical and radiographic findings of only the midcervical region are rare. A cadaver study describing bony changes localised to the cervical articular processes described a similar pattern. With mostly mild-to-moderate changes observed, mild changes were mainly localised at C3-6, moderate changes at C6-T2 and severe changes at C2-3 and C6-T2 (Haussler *et al*. 2019). This is most likely due to the limited contribution of the midcervical region in the flexion-extension and lateroflexion movements (Clayton and Townsend 1989; 1989a). The limited local stresses in the midcervical region as compared to the head and neck posture, during the cranial and cervical thoracic transition in the caudal cervical region, should also be considered (Haussler *et al*. 2019).

In a previous report, the inability to grade the left and right cAPJs separately on laterolateral projections, in case of asymmetric enlargement, was considered a limitation (Down and Henson 2009). Additionally, in our study, we could not specify the side of asymmetric enlargement, because only laterolateral projections were included for review. However, asymmetric enlargement in itself can be detected on laterolateral projections. In our experience, asymmetric enlargement can be clinically present with limited lateroflexion both towards and away from an asymmetrically enlarged cAPJ. Recognising the asymmetry of the cAPJs was considered an important radiographic finding and a possible explanation of limited lateroflexion in the cervical spine (personal experience). In future research, the evaluation of additional oblique projections (Withers *et al*. 2009) or comparison between the right lateral and left lateral projections (Butler *et al*. 2008) may possibly show an association between the specific clinical findings and asymmetrically enlarged cAPJs.

Similar to the asymmetry issue, only the presence of radiolucent or areas with increased opacity in cAPJs can be recognised on laterolateral projections. However, the inability to locate these lesions exactly does not alter their presence. Therefore, inclusion of these findings in the grading system is justified. Referral for computed tomographic (CT) evaluation may be advised for exact location of these abnormalities within the cAPJs if treatment were considered (Kristoffersen *et al*. 2014). Recently, the use of CT for the cervical area in horses has been reported. CT imaging is more advanced and provides better anatomical detail as compared to radiography (Kristoffersen *et al*. 2014), especially with respect to the joint surfaces of the articular processes. However, general anaesthesia is needed to perform a complete examination (i.e. from occiput to T1), which is a major disadvantage. Therefore, CT is not considered a modality for the primary evaluation of the cervical region. Hence, radiography is most likely to remain the primary imaging modality for the cervical region, due to its easy availability and performance in a standing sedated horse.

Changes at the level of the occiput have not been studied in previous reports. Given the significant association between radiographic grades and clinical signs, changes at the level of the occiput are likely to have clinical relevance. To achieve correct evaluation of the occiput, it is important that the auricular cartilages do not superimpose over it. The irregularities in the auricular cartilages can cause over-interpretation of the findings in the caudal occiput area.

Intra- and intervertebral ratios, and minimum intercentral joint space widths showed a large variability in the studied population. No significant differences between the clinically affected and control groups were detected for these measurements and the grading of the intercentral joint space. These results corroborated with previous reports (Dyson 2011).

Due to the limited neurological cases included in the study population, it was out of the scope of this study to compare those to a control group. However, it has to be stressed that all the neurologically abnormal horses (n = 7)

also showed values below the previously reported threshold of 0.485 for the minimum sagittal diameter (Hahn *et al*. 2008). In future studies, it would be interesting to follow-up with these cases in more detail.

Morphologic variations of the ventral lamina of C6 have been described in various populations (DeRouen *et al*. 2016; Veraa *et al*. 2016). In previous mixed populations including 78 and 100 horses, similar distributions were found as reported in this study. In the results presented in this study (P = 0.99) and the results described by Veraa *et al*. (2016) (P = 0.81), no significant associations between the conformation of C6 and clinical signs was found. DeRouen *et al*. (2016) described a significant association between C6 morphology and clinical presentation (P = 0.013). Review of the population data provided by DeRouen *et al*. (2016) comprising of different populations used for the case group and the control group, showed an over-representation of Warmbloods in the case group (P = 0.006). A population bias has to be considered as both our results and the results described by Veraa *et al*. (2016) neither confirm the predilections of the breed, nor the distribution in clinical findings.

Significant associations between the anatomical variation of the spinous process of C7 and T1 are in accordance with a previous report investigating a mixed population (Scrivani *et al*. 2011). However, there was no association established with clinical findings. Thus, there is no indication that these variants have a clinical relevance in Dutch Warmbloods.

All clinical examinations were performed by a select group of three clinicians with at least 15 years of clinical orthopaedic experience using a similar protocol. A limitation in this retrospective study was that only localisation of the clinical complaints was used from the recorded data. The amount of combinations of symptoms described in the clinical records did not allow cases to be specifically assigned to groups based on clinical complaints for further meaningful statistical analysis. Moreover, the clinical records were retrospectively reviewed, allowing for a biased recording of the clinical data after reviewing the radiographic examination.

More standardised reporting on complaints would be interesting in future research to distinguish between specific clinical complaints and radiological signs. Furthermore, this study only included Dutch Warmblood horses, and even though the sample size was large, the study population may not be representative of the entire Dutch Warmblood population. The presented results should be interpreted bearing in mind that the pattern of referral for cervical radiographic examination and patterns seen within the entire population can vary.

Conclusion

In addition to abnormalities in size, the periarticular modelling, asymmetry, radiolucencies, increased opacity and fragmentation in the presented radiographic grading system allowed evaluation of all cAPJs. Furthermore, this radiographic grading system helped to interpret an association between the radiographic grading and clinical complaints. Knowledge of the distribution of these radiographic findings and their associated clinical relevance is important to reach a science-based diagnosis in daily practice.

Authors' declaration of interests

No competing interests have been declared.

Ethical animal research

Research ethics committee oversight not required by this journal: retrospective analysis of clinical data.

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Authorship

C. P. Crijns contributed to study design, study execution, data analysis and manuscript preparation. B. J. G. Broeckx contributed to study design, data analysis and manuscript preparation. Both authors gave their final approval of their manuscript.

Manufacturers' addresses

[1]Agfa-Gevaert NV, Mortsel, Belgium.
[2]OsiriX, Open Source, http://www.osirix-viewer.com.
[3]R version 3.1.2, Open Source, https://cran.r-project.org.

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Review Article

Overview of the use of antimicrobial drugs for the treatment of bacterial infections in horses

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Keywords: horse; antimicrobial stewardship; therapy

Summary

The use of antimicrobials in veterinary medicine is under great scrutiny with the emergence of antimicrobial resistance in the human population. Equine veterinarians rely on antimicrobials as an essential tool for the treatment of infections in horses, but there is much criticism of some use, particularly prophylaxis. While the appropriate use of antimicrobials can be justified in equine medicine, the misuse cannot. The definition of appropriate use is complex and involves the indication for therapy, antimicrobial selection, dosing regimen and timing and route of administration, duration of therapy and modification of therapy based on microbial susceptibility and clinical response. The aim of this article is to provide guidance on these factors to assist equine veterinarians in determining what constitutes appropriate antimicrobial use in horses.

Introduction

Antimicrobial resistance (AMR) is a global health emergency. The O'Neil report to the UK government predicts by 2050, approximately 10 million people will die each year from drug-resistant infections and that AMR will cost the global economy over $140 trillion annually (O'Neil, The Review on AMR, 2016). The use of antimicrobials in veterinary medicine is under great scrutiny with the emergence of antimicrobial resistance in the human population. Some antimicrobial-resistant pathogens are believed by some to be the result of the use of antimicrobials in veterinary medicine, particularly the use of antimicrobials with high importance to human medicine. However, veterinarians rely on antimicrobials as an essential tool for treatment of infections in animals. While the appropriate use of antimicrobials can be justified in veterinary medicine, the misuse cannot. The purpose of this article is to review and provide guidance on what constitutes appropriate use of antimicrobials in horses.

Importance rating of antimicrobials to human health

The World Health Organization (WHO) publishes a 'Critically Important Antimicrobials for Human Medicine' list which represents a global list ranking antimicrobial agents according to their importance to human health (World Health Organisation, 2019). Countries can use this list directly, especially those with limited resources, for risk prioritisation of nonhuman use of antimicrobials. However, to account for national considerations and local context, government agencies are encouraged to create relevant importance lists for prescribers in their own jurisdictions. The WHO recognises that recommendations may vary from country to country, with national documents taking precedence over that of the WHO (Australian Strategic and Technical Advisory Group on Antimicrobial Resistance, 2018). The authors recommend that equine veterinarians make themselves aware of national antimicrobial importance ranking guidelines, along with other prescribing guidance from professional bodies and other organisations, where available. Prescribers should prioritise the use of antimicrobials with the lowest importance to human medicine, to preserve the effectiveness of important antimicrobials for both veterinary and human medicine. A list of common antimicrobials in equine medicine, and their relative importance to human medicine according to the WHO and other jurisdictions, is shown in **Table 1**. An explanation of the terminology can be found in **Supplementary Item 1**. Those antimicrobials that are critically important (WHO, Japan, USA), high importance (Australia), very high importance (Canada) and level A (European Union) should not be used empirically, except under exceptional circumstances such as life-threatening infections. These antimicrobials should be used in conjunction with culture and susceptibility testing, with de-escalation following culture results where appropriate (see below).

What constitutes appropriate use?

Appropriateness of antimicrobial use is complex and involves many factors **Table 2**. Firstly, a bacterial indication for antimicrobial therapy must be present. This indication should be such that the horse is unlikely to recover without antimicrobial therapy, and there is a reasonable likelihood that therapy will result in a positive response. For example, a yearling with a draining strangles abscess has a bacterial disease but is likely to recover without antimicrobial therapy, so antimicrobials are not indicated. However, a horse with a septic synovial structure is unlikely to recover without antimicrobials and has a good chance of responding to a combination of local and systemic treatment (including lavage), so therapy is appropriate.

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TABLE 1: Antimicrobial importance rating according to jurisdiction

	WHO (World Health Organization 2019)	Australia (Australian Strategic and Technical Advisory Group on Antimicrobial Resistance 2018)	Canada (Health Canada 2009)	Japan (Food Safety Commission Japan 2014)	European Union (European Medicines Agency 2019)*	USA (Food and Drug Administration 2003)
Metronidazole	Important	Medium	Very high	Important	D	Highly important
Penicillin	Highly important	Low	High	Highly important	D	Highly important
Oxytetracycline	Highly important	Low	Medium	Important	D	Highly important
Doxycycline	Highly important	Low	Medium	Important	D	Highly important
Trimethoprim–sulphonamide	Highly important	Medium	High	Highly important	D	Critically important
Chloramphenicol	Highly important	Low	Medium	Highly important	C	Highly important
Gentamicin	High priority critically important	Medium	High	Highly important	C	Highly important
Amikacin	High priority critically important	High	High	Highly important	C	Highly important
Erythromycin/ Clarithromycin/ Azithromycin	Highest priority critically important	Low	High	Highly important	C	Critically important
Rifampin	High priority critically important	High	Very high	Critically important	A	Highly important
Ceftiofur	Highest priority critically important	High	Very high	Critically important	B	Critically important
Enrofloxacin	Highest priority critically important	High	Very high	Critically important	B	Critically important
Vancomycin	Highest priority critically important	High	Very high	Critically important	A	Highly important

* European Union classification: A = avoid; B = restrict; C = caution; D = prudence

The second criterion for appropriate antimicrobial use is antimicrobial selection. Most therapy in equine medicine is empiric. It is critical that this empiric therapy is selected with knowledge of likely pathogens, intrinsic and acquired resistance patterns, and good knowledge of pharmacology. For example, *Streptococcus zooepidemicus* is the most common cause of pneumonia in horses and beta-haemolytic streptococcal species have predictable susceptibility to penicillin. In addition, penicillin has relatively low importance to human health so is an appropriate therapy for streptococcal diseases in horses. However, *Staphylococcus* spp. have unpredictable susceptibility profiles and in scenarios where staphylococci are suspected, culture and susceptibility testing should be performed. In addition, antimicrobials should be selected based on their predicted penetration into the site of infection. For example, when treating meningitis in foals, penicillin and gentamicin both have very poor penetration of the blood-brain barrier however trimethoprim–sulphonamide has excellent penetration and may be a more appropriate empiric antimicrobial choice in this scenario. A discussion on the spectrum of action of common equine antimicrobials is presented below.

The third factor is a dose regimen that is likely to result in therapeutic concentrations of antimicrobials at the site of infection. For example, time-dependent antimicrobials (e.g. penicillin) require more frequent dosing than concentration-dependent antimicrobials (e.g. gentamicin). In addition, foals may require higher doses than adults for some antimicrobials (e.g. aminoglycosides) because they have a higher percentage of body water, which leads to a significantly larger volume of distribution. Drug dosing in relation to antimicrobial labels is discussed in further detail below.

The fourth criterion is timing of antimicrobial therapy. Timing of antimicrobial administration is critical for some scenarios, such as surgical prophylaxis. To prevent surgical site infections, antimicrobials must be present at effective concentrations at the operative site at the time of first incision. When using intravenous formulations, administration 30–60 min prior to first incision is generally adequate. In comparison, for intramuscular formulations the time to maximal concentration can be used to determine optimal timing. For procaine penicillin, this requires administration 3.5 h prior to the first incision (Uboh *et al*. 2000). The repeat intraoperative dosing interval is determined as twice the elimination half-life of the antimicrobial and should be measured from the time of the preoperative dose. This is generally only required for intravenous formulations with short half-lives. For example, for sodium benzyl penicillin repeat dosing should be provided during surgery every 80 min (Horspool and McKellar 1995), while repeat intraoperative doses of gentamicin are unlikely to be needed (twice half-life = 6 h). Further guidance on using antimicrobials for surgical prophylaxis is available from the British Equine

TABLE 2: Factors contributing to appropriate antimicrobial use

Factors	Criteria for appropriateness
Indication	• A bacterial disease is present • Patient is unlikely to recover without antimicrobial therapy • Patient is likely to respond to antimicrobial therapy
Antimicrobial selection	• Empirical therapy is chosen with knowledge of likely bacterial pathogen and resistance patterns • Antimicrobials of low importance to human health are prioritised • Narrow spectrum antimicrobials are chosen in preference to broad-spectrum agents where possible • Diagnostic tests are utilised when appropriate and always when critically important antimicrobials are used
Dosing	• A dosing regimen is used that is likely to result in appropriate concentrations at the site of infection
Timing	• Antimicrobials are used at a time when they are most likely to treat or prevent disease (especially for surgical prophylaxis)
Route of administration	• Topical or local therapy is selected over systemic therapy when possible
Duration of therapy	• Duration is restricted to the shortest possible length of therapy while still effectively treating the disease
Modification of therapy	• Treatment is reviewed regularly and escalated or de-escalated based on results of culture and susceptibility testing (when performed) and clinical response • Empirical therapy should be given sufficient time to evaluate a response (48–72 h) before changing antimicrobials empirically

*Note that any deviation from the data in the marketing authorisation constitutes off-label use, which may carry legal responsibilities.

Veterinary Association (British Equine Veterinary Association 2016) and the Australian Veterinary Prescribing Guidelines (Asia Pacific Centre for Animal Health and National Centre for Antimicrobial Stewardship 2017).

Route of administration is the fifth criterion. Topical or local administration (e.g. intra-articular [IA] and intravenous regional limb perfusions [IVRP]) results in less systemic absorption and therefore likely has less effect on the gastrointestinal microbiome of patients than systemic therapy. In addition, due to the extremely high concentrations of antimicrobials achieved in the treated tissue, these routes of administration are also likely to be more efficacious for infections occurring in the distal limbs and joints. However, some limitations exist. For intermittent therapy (not continuous rate infusions), antimicrobials that are concentration-dependent (e.g. aminoglycosides such as gentamicin and amikacin) are most appropriate for IA or IVRP routes. Time-dependent antimicrobials (e.g. penicillins, cephalosporins, trimethoprim–sulphonamide) rely upon maintaining a tissue concentration of antimicrobials above the minimum inhibitory concentration (MIC) for most of the inter-dosing interval, so achieving a very high concentration is of no benefit in effective treatment. In contrast, concentration-dependent antimicrobials exhibit a post-antibiotic effect, the length of which is proportionate to the peak concentration making them extremely useful for local therapies (MacKenzie and Gould 1993). Care is needed as some concentration-dependent antimicrobials can cause severe local inflammatory reactions (e.g. enrofloxacin) that make them unsuitable for local therapy (Parra-Sanchez *et al*. 2006). Topical therapy with antimicrobials has very little evidence base; however, topical therapy with antiseptics (for superficial dermatitis e.g. rain scald or draining abscesses) can be very useful in avoiding the need for systemic antimicrobial therapy (Awad *et al*. 2008).

The sixth criterion is duration of therapy. The mantra on duration of therapy has shifted in recent times. Duration should be restricted to the shortest effective duration. There is much research in human medicine to support shorter durations of therapy for conditions such as community-acquired pneumonia, for which treatment duration has decreased from 10 days to 3 days (Hanretty and Gallagher 2018). In equine medicine, evidence is emerging. There was no difference in surgical site infection rate for horses treated with 72 h compared to 120 h of post-operative prophylaxis for surgical colic cases (Durward-Akhurst *et al*. 2013). In some cases, antimicrobial therapy has been shown to be unnecessary. For elective arthroscopy, there was no difference in the rates of joint sepsis between horses administered pre- or perioperative antimicrobials and those that received none (Borg and Carmalt 2013). Antimicrobials are used extensively for prophylaxis in equine medicine, a use that draws much criticism across jurisdictions, and the extensive use of antimicrobials in surgery, and for extended

durations after surgery, is likely unnecessary. The challenge in selecting duration of therapy for bacterial diseases is knowing when the infection is resolved. For a few syndromes, this is straightforward, such as bacterial keratitis or metritis, but for many it is not. It is important to understand, however, that the origins of the traditional durations of therapy are not borne from evidence and are mostly 5 or 7 days or replicative thereof. It is likely that evidence from companion animal and human medicine will be replicated in equine medicine, and the duration of therapy required to resolve many infections is far shorter than those we have traditionally used. For example, in dogs with uncomplicated urinary tract infections (Clare *et al*. 2014) there is evidence that short-duration therapy (3 days) is as effective as longer duration therapy (10 days). Similarly in human medicine, there is evidence for short duration of therapy for sinusitis (Falagas *et al*. 2009), pyelonephritis (Kyriakidou *et al*. 2008), community-acquired pneumonia (Hanretty and Gallagher 2018), intra-abdominal infections (Hanretty and Gallagher 2018), skin and soft tissue infections (Hanretty and Gallagher 2018) and numerous others. Equine practitioners should regularly review the need for therapy, and for uncomplicated infections trial shorter durations of therapy such as those described in the research above. In addition to reducing the selection for resistance, decreasing the duration of therapy has other benefits for equine owners. There is reduced cost associated with medications, compliance is likely to be improved, and fewer adverse events would be predicted.

Finally, escalation and de-escalation of therapy should be performed in response to culture and susceptibility results. This is based on the concept of using the lowest importance antimicrobial possible to reduce the selection of bacteria with resistance to antimicrobials that are critically important to human medicine. This is also important for antimicrobial sustainability in equine practice. With reports of antimicrobial resistance in horses on the rise, combined with the scarcity of new antimicrobials being commercialised, equine veterinarians also face the prospect of pan-resistant pathogens if antimicrobials are not used responsibly. In the scenario where a cultured pathogen is susceptible to an antimicrobial with lower importance to human medicine than the empiric choice, therapy should be de-escalated to this lower importance agent. Similarly, if a patient is on broad-spectrum antimicrobials empirically and a single pathogen is cultured, therapy should be de-escalated to a narrower spectrum antimicrobial. The reverse is also true, however, if susceptibility results suggest empiric therapy of a low importance antimicrobial is insufficient, and there has been no clinical response, then therapy should be escalated based on susceptibility results to an agent that is likely to be effective. Clinical response should also be considered. In vitro susceptibility testing may not accurately depict the tissue concentrations achieved, especially with local therapy (IA, IVRP). For this reason, clinical response may be evident even if susceptibility results suggest therapy would be ineffective. The addition of antimicrobials to therapeutic regimens, without thought as to the implications such as drug interactions, is not appropriate. Where samples were not obtained for culture at the beginning of therapy and first-line empiric therapy fails, samples for culture should be obtained for an empiric therapeutic change to avoid poor outcomes associated with ineffective therapy over a prolonged period.

Inappropriate uses of antimicrobials in equine practice

Inappropriate use of antimicrobials is common in equine practice (Weese and Sabino 2005; Hughes *et al*. 2013; Hardefeldt *et al*. 2017). Inappropriate use can be due to a variety of factors. Firstly, antimicrobials can be used when there is no bacterial infection present. The prophylactic use of antimicrobials in equine practice has been identified as a major concern by regulators, particularly in Europe. Examples include use of a monthly pulse of antimicrobials for placentitis prevention or administration of antimicrobials to horses with signs consistent with equine asthma (cough and nasal discharge). Another example is where antimicrobials are used for their nonantimicrobial effects, such as doxycycline for its matrix metalloproteinase (MMP) effects. There are other nonantimicrobial agents that have similar MMP effects that can be used in keratomalacia such as ETDA and autologous serum and are more appropriate than doxycycline.

A combination of factors may be driving equine veterinarians to prescribe in these circumstances including pressure, or perceived pressure, from clients and a fear of deterioration in a patient leading to litigation (Hardefeldt *et al*. 2018). Also, the inappropriate use of antimicrobials is often seen as unlikely to cause harm. However, a change in mindset is required in the equine sector to recognise the role prescribing plays in the emergence of antimicrobial resistance, which is affecting equine patients, and contributing to loss of social licence as a profession.

Under-dosing of antimicrobial agents is another common form of inappropriate use. In an Australian study, up to 30% of antimicrobial doses were insufficient to reach tissue levels above minimum inhibitory concentrations for common equine pathogens (Hardefeldt *et al*. 2017). Appropriate dosing with antimicrobial agents is critical for effective treatment and also in the fight against AMR. All antimicrobial use can select for AMR, but exposure to subtherapeutic levels of antimicrobial agents may increase the rate of development of AMR, particularly when exposure is prolonged or recurrent (Guillemot *et al*. 1998; Liu *et al*. 2011; Gullberg *et al*. 2011). The reasons for subtherapeutic dosing regimens being selected by veterinarians are likely complex and include behavioural drivers that are poorly understood. There are some clear influencing factors, however, including antimicrobial labels where some doses recommended on the product label fall below those now recognised as appropriate. This has been discussed in depth elsewhere (Hardefeldt *et al*. 2018; Hardefeldt 2019).

While inappropriate use is common, there is evidence that education and antimicrobial stewardship can reduce inappropriate prescribing in veterinary medicine and in particular reduce use of critically important antimicrobials (De Briyne *et al*. 2014; Speksnijder *et al*. 2015), although not specifically in horses. Antimicrobial stewardship in equine practice has recently been reviewed (Prescott 2021).

Off-label antimicrobial use

To exert a stronger influence on antimicrobial stewardship, regulatory restrictions on off-label use of veterinary

TABLE 3: Antibiogram for empiric therapy of common equine pathogens

	Drugs											
Bug	Procaine benzylpenicillin	Ampicillin	Doxy-cycline	Oxytetra-cycline	Trimethoprim sulpha	Chloram-phenicol	Gentamicin	Metron-idazole	Ceftiofur	Clarithromycin or Azithromycin + rifampin*	Enrofloxacin	
Beta-haemolytic streptococci	✓	+	±	±	±	+	IR		+		+	
Staphylococcus aureus†	±		±	±	±	+	±				+	±
Enterococcus faecalis†	+	✓	±	±	IR	±	IR		IR		±	
Enterococcus faecium†			±	±	IR	±	IR		IR		±	IR
Rhodococcus equi										✓		
Escherichia coli†	IR	±	±	±	±	±	✓		+		+	+
Klebsiella spp. †	IR	IR	±	±	±		✓		±		±	
Enterobacter spp. †	IR	IR	±	±	±	±	±		±		+	+
Pseudomonas aeruginosa†	IR	IR	IR	IR	IR	IR	✓		IR		±	
Actinobacillus equuli	±	±	✓	✓	✓	±	✓		+		+	+
Pasteurella spp.	✓	+	+	+	±	±	✓		+		+	
Salmonella spp. †		±	+	+	±		±					±
Lawsonia intracellularis			✓	✓								
Bacteroides spp.	IR	IR	±	±		+	IR	+				IR
Clostridium spp.	✓	+	±	±			IR	+	±			

✓, drug of choice; + good susceptibility; ± variable susceptibility; IR, intrinsically resistant.
Traffic light system is based off ASTAG rating system for importance of antimicrobials. From U. Melbourne and Equine Veterinarians Australia pocket guide for antimicrobial therapy (Asia Pacific Centre for Animal Health and National Centre for Antimicrobial Stewardship, 2017).
* Clarithromycin or Azithromycin + rifampin should not be used in adults
† Susceptibility is poorly predicable, culture and susceptibility testing are strongly recommended

TABLE 4: Antibiotic pharmacotherapy by class

Drug class	Antibiotic	Route	Drug dose	Adverse reactions	Clinical pearls
Beta-lactams	Procaine benzylpenicillin	IM	22,000 IU/kg (22 mg/kg) q. 12 h	Diarrhoea. Procaine reaction: Inadvertent intravascular administration of procaine resulting in CNS excitation and frantic, uncontrollable behaviour that generally resolves in minutes. Penicillin hypersensitivity reactions: urticaria, anaphylaxis, immune-mediated haemolytic anaemia.	Drug of choice for streptococcal infections. Excellent anaerobic activity (except *Bacteroides* spp.). Often combined with gentamicin for broad-spectrum coverage. Always draw back to check for blood before injecting and keep penicillin refrigerated to reduce risk of procaine reaction. Long-acting penicillin formulations are not suitable for use in horses as they are not long-acting and do not reach therapeutic concentrations.
	Benzylpenicillin	IV	22,000 IU/kg (13 mg/kg) q. 4–6 h		
		IU	5 million IU for *Streptococcus zooepidemicus*	Secondary bacterial infection, fungal infection.	Uterine lavage and ecbolics are the primary focus of endometritis therapy. Uterine fluid/exudate may inactivate or dilute antibiotics. Inactivated in solutions with pH < 5.5 or > 8, do not mix with gentamicin, sulphonamides or sodium bicarbonate. Antibiotic use should be guided by culture, cytology and ultrasound findings.
	Ampicillin sodium	IV/IM	20 mg/kg q. 6–8 h	Ampicillin trihydrate irritant when injected IM.	Greater activity against gram-negative bacteria than penicillin.
	Ceftiofur	IM/IV	2.2–4.4 mg/kg q. 12–24 h (Up to 10 mg/kg i.v. q. 6 h has been used in neonatal foals)	Diarrhoea, muscle soreness, hypersensitivity – urticaria, anaphylaxis.	Should be reserved for multi-drug-resistant infections. Does not cross BBB. Ceftiofur is rapidly metabolised to desfuroylceftiofur to which most coagulase-positive staphylococci are resistant (may appear susceptible *in vitro* but not *in vivo*).
	Ticarcillin–clavulanate				
Aminoglycosides	Gentamicin	IM/IV IM/IV	6.6–9.7 mg/kg q. 24 h (adults) 8.8–12 mg/kg q. 24–36 h (foals)	Nephrotoxic when administered to horses that are dehydrated or hypovolaemic, or when given for prolonged durations. Muscle soreness if given IM. Hypersensitivity reactions (rare).	Generally, drug of choice for suspected or confirmed gram-negative infections. No anaerobic activity. Streptococci and enterococci are intrinsically resistant. Inactivated by purulent material. Must penetrate bacteria to assert their effect, which is enhanced by drugs that interfere with cell wall synthesis – for example penicillin. Not effective *in vivo* against *Salmonella* spp. but may appear susceptible *in vitro*. If kidney function is reduced, increase inter-dosing interval.
		IU	1–2 g buffered with equal volume of 7.5% bicarbonate and diluted in 200 mL saline	Irritates endometrium or induce depigmentation of vulvar skin if not buffered. Secondary bacterial infection, fungal infection.	
	Amikacin	IV	10 mg/kg q. 24 h (adults)	Nephrotoxic when administered to horses that are dehydrated or hypovolaemic, or when given for prolonged durations.	Use severely restricted in human medicine. Not registered for use in animals and should not be used off-label except in exceptional circumstances. Reserve for documented gentamicin resistant, amikacin susceptible infections where no alternative. No anaerobic activity. Streptococci and enterococci are intrinsically resistant. Inactivated by purulent material. Not effective clinically against *Salmonella* spp. but may appear susceptible *in vitro*. Can be used IA.

TABLE 4: Continued

Drug class	Antibiotic	Route	Drug dose	Adverse reactions	Clinical pearls
Tetracyclines	Doxycycline	PO	10 mg/kg q. 12 h	Diarrhoea. Bone/tooth discolouration. DO NOT GIVE IV – FATAL.	Excellent broad-spectrum activity, good anaerobic coverage but variable for Bacteroides and Clostridium spp. Drug of choice for *Lawsonia intracellularis* infection. Doxycycline bioavailability reduced by feeding; withhold feed before and shortly after dosing. Doxycycline can be used in horses with renal failure. Distributes well into pulmonary, peritoneal and synovial fluid and concentrates in urine.
	Oxytetracycline	IV	6.6 mg/kg q. 12 h	Hypotension and collapse if rapid IV administration of oxytetracycline. Renal tubular necrosis with high doses (e.g. for neonatal foals with contracted tendons). Bone/tooth discolouration. Colitis. Very irritant if extravascular or intramuscular.	Excellent broad-spectrum activity, good anaerobic coverage but variable for Bacteroides and Clostridium spp. Drug of choice for *Lawsonia intracellularis* infection. Distributes well into pulmonary, peritoneal and synovial fluid and concentrates in urine. High dose oxytetracycline causes tendon relaxation in foals with congenital contracted tendons (not acquired) and is most efficacious when given in the first 3 days of life (20 mg/kg IV). Care in foals that are, or may be, dehydrated due to renal effects; consider administration in 1L Hartmanns.
Sulphonamides	Trimethoprim–sulphonamide	PO/slow IV	30 mg/kg q. 12 h	Diarrhoea. Thrombocytopaenia with prolonged use. Rapid IV administration can cause tremors and collapse. Concurrent detomidine can result in dysrhythmia, hypotension and death. Concurrent penicillin is antagonistic to sulphonamides. Irritant if given IU or IM.	Excellent broad-spectrum activity. Inactivated by purulent material. Undergoes urinary excretion therefore useful for urinary tract infections.
Macrolides	Erythromycin Clarithromycin Azithromycin	PO PO PO	25 mg/kg q. 6 h 7.5 mg/kg q. 12 h 10 mg/kg q. 24 h	Severe colitis in adults, variable diarrhoea in foals. Altered thermoregulation in foals (hyperthermia), which seems more common with erythromycin.	Do not use in adults. Generally, only used in foals with *Rhodococcus equi*, in combination with rifampin. Can be used in young foals with *Lawsonia intracellularis* infection but not first-line choice.
Ansamycin	Rifampin	PO	5 mg/kg q. 12 h	Body fluids turn orange. Antagonistic to gentamicin.	Empiric use only for suspected *Rhodococcus equi*, in combination with a macrolide. Otherwise only use in exceptional circumstances based on culture and susceptibility and no effective alternative. Never use alone, resistance can develop within hours when used as monotherapy.
Fluoroquinolones	Enrofloxacin	PO/slow IV	7.5 mg/kg q. 24 h	OCD in young horses. DO NOT USE IM, IA, IU or as IVRP as causes necrosis and fibrosis. Oral paste has been	Should be reserved for multi-drug-resistant infections based on culture and susceptibility results with no effective lower importance

TABLE 4: Continued

Drug class	Antibiotic	Route	Drug dose	Adverse reactions	Clinical pearls
				associated with severe oral ulceration. Colitis. Fluoroquinolone have also induced tendonitis in juveniles.	rating option. Generally avoided in horses < 4 years of age and during pregnancy. Synergism with beta-lactams and aminoglycosides.
Nitroimidazoles	Metronidazole	PO	25 mg/kg q. 12 h	Inappetence. Can cause neurological signs if underlying hepatic disease.	Excellent anaerobic activity. Use is generally combined with penicillin and gentamicin for broad-spectrum coverage where anaerobes are suspected to be contributing (pleuropneumonia, peritonitis). Indicated in cases where Bacteroides spp. may be involved.
Phenicols	Chloramphenicol	PO	50 mg/kg q. 12 h	Wear gloves and mask when crushing tablets for horses as idiosyncratic aplastic anaemia (not dose-related) can develop in people handling this drug. In horses, dose-related anaemia and pancytopenia may develop with prolonged treatment.	Broad spectrum. Prohibited for use in animals that may enter the food chain. Check legislation in your jurisdiction. Do not give concurrently with penicillin, gentamicin, fluoroquinolones or macrolides. Hepatic clearance decreased by phenytoin, phenobarbital, phenylbutazone and xylazine.
Polypeptides	Polymyxin B	slow IV	5000 U/kg q. 8–12 h (anti-endotoxic dose)	Potentially nephrotoxic. Caution in severely dehydrated, hypovolaemic or azotaemic patients and with concomitant administration of other nephrotoxic drugs such as NSAIDs and gentamicin.	Generally, only used systemically to combat endotoxaemia. Care should be taken as endotoxic patients often have impaired renal perfusion.
Streptogramins	Virginiamycin	PO	5 g/100 kg q. 24 h	High importance antimicrobial – banned for Equine use in UK 2014	Reduces fermentative acidosis in the hindgut and may aid in the prevention of pasture-associated laminitis.
Other	Sodium iodide	IV	20–40 mg/kg q. 24 h	Iodinism	Generally used for chronic fungal or bacterial infections where antimicrobial penetration may be poor.

antimicrobials are being increasingly discussed. This has the potential for remarkable ramifications for equine practitioners as on-label use does not equate to prudent use, and in-fact, off-label use may equate to appropriate use. If off-label use becomes restricted, veterinarians would be obliged to follow all label recommendations. Penicillin carries outdated dosing information on the label in Australia (Australian Pesticides and Veterinary Medicines Authority 2017), the USA (Daily Med 2020) and the UK (Veterinary Medicines Directorate 2020). Gentamicin is only labelled for intrauterine use in the USA (Daily Med 2020) and carries inaccurate dosing information in Australia (Australian Pesticides and Veterinary Medicines Authority 2017). Veterinarians would also be restricted to using antimicrobials licensed for use in horses, negatively impacting antimicrobial stewardship by preventing the use of low importance antimicrobials such as doxycycline. It is likely that similar scenarios exist in other countries. It is essential that equine veterinarians are aware of off-label antimicrobial use restrictions in their jurisdictions and actively participate in discussions at government levels on the implications of off-label restrictions.

Nevertheless, there are many scenarios where off-label antimicrobial use is not justified in equine practice. Off-label use of human formulations of antimicrobials, where an agent of lesser importance to human medicine is likely to be effective and safe, cannot be justified. The widespread first-line use of amikacin IA, where gentamicin would be effective, is an example of this. Also, the intrauterine use of antibiotics as prophylaxis for post-service endometritis, such as ticarcillin–clavulanate, is unjustified unless culture and susceptibility testing confirms that the pathogen is resistant to all antimicrobials with lesser importance to human health.

Spectrum of action of common equine antimicrobials

Knowledge of the spectrum of action, likely susceptibility patterns and adverse effects, is necessary for quality use of equine antimicrobials. We recently collated this information in a pocket guide to antimicrobial therapy in horses (Asia Pacific Centre for Animal Health and National Centre for Antimicrobial Stewardship 2017). **Tables 3** and **4** give an overview.

In conclusion, AMR is a health emergency not only for the medical profession but also for veterinarians. Appropriate use of antimicrobials is paramount and requires reassessment of prescribing habits by all or risk losing the freedoms we currently rely on to make good prescribing decisions. Veterinarians must consider the importance of antimicrobials to human health when they prescribe and should make themselves aware of national guidance where it exists. Antimicrobial prescribing guidelines are becoming increasingly common for equine syndromes, and these present the most up-to-date information on appropriate therapy (British Equine Veterinary Association 2016, Asia Pacific Centre for Animal Health and National Centre for Antimicrobial Stewardship 2017).

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Authorship

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Supporting information

Additional Supporting Information may be found in the online version of this article at the publisher's website:

Supplementary Item 1. Definitions of antimicrobial importance according to organisation.

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Correspondence

Letter to the Editor: Regarding recent paper by Pezzanite et al.

The recent paper by Pezzanite *et al*. (2020) raised a variety of important points concerning the challenges of accurate diagnosis of proximal metacarpal and metatarsal region pain. We would like to enlarge on some aspects of the clinical investigation.

Firstly, it is important to pay attention to clinical features, as pointed out by the authors and highlighted in a recent editorial (Dyson 2018a). These features do not provide a specific diagnosis but add important information for interpretation of diagnostic anaesthesia and imaging findings. Pain on palpation in the region of origin of the suspensory ligament may reflect osseous, bone/ligament interface disruption or soft tissue pathology, but may be absent. A pain response to carpal flexion, as reported by Pezzanite *et al*. (2020), would be a very unusual finding in association with forelimb proximal suspensory desmitis, whereas mild pain on palpation of the body of the suspensory ligament is a not uncommon nonspecific clinical observation. The severity of lameness should be matched with the ultimate clinical diagnosis; if this is not the case, consider that there may be another anatomical structure contributing to pain. However, as discussed more comprehensively elsewhere (Pilsworth and Dyson 2015), several closely related anatomical structures may be contributing to pain and lameness. For example, we have previously demonstrated using MRI the coexistence of abnormal mineralisation of the third carpal bone and syndesmopathy between the second and third metacarpal bones (Nagy and Dyson 2012).

Whilst acknowledging that none of the techniques for local anaesthesia of the proximal metacarpal and metatarsal regions is specific, the authors (Pezzanite *et al*. 2020) make an assumption that 60% improvement in lameness is sufficient. We would challenge this and suggest that with primary proximal suspensory injuries, we would expect to observe at least 90% improvement in lameness in forelimbs (Gruyaert *et al*. 2020) and ≥80% improvement in lameness in hindlimbs (Dyson and Murray 2012), with residual lameness being abolished by ulnar or tibial nerve blocks in forelimbs and hindlimbs, respectively. The need to add ulnar or tibial nerve blocks would also prompt careful ultrasonographic assessment for the detection of possible adhesions between the suspensory ligament and adjacent osseous and soft tissue structures (Dyson *et al*. 2017, 2018), and assessment of the accessory ligament of the suspensory ligament (Dyson 2014), the accessory ligament of the deep digital flexor tendon (Dyson 2012; Plowright and Dyson 2015) and in hindlimbs, the lateral digital flexor tendon (Davis *et al*. 2014).

Alternatively, the residual lameness may be abolished by intra-articular analgesia of the middle carpal joint or tarsometatarsal joint. Consideration must also be given to unrelated more proximal sources of pain contributing to pain and lameness, for example the sacroiliac joints (Barstow and Dyson 2015). We recommend that, unless clinically contraindicated to do so by the severity of lameness, we should aim to achieve 90% improvement in baseline lameness, whilst acknowledging that, for a variety of reasons (Pilsworth and Dyson 2015), this is not always possible.

Even with ≥80% improvement in lameness after apparent desensitisation of the proximal palmar metacarpal or plantar metatarsal region, we must always consider that the primary source of pain may be the carpus or tarsus, respectively, as discussed more fully elsewhere (Pilsworth and Dyson 2015) and illustrated by clinical and imaging descriptions in the forelimbs (Nagy and Dyson 2012) and the hindlimbs (Daniel *et al*. 2012; Davis *et al*. 2014; Dyson 2013). Ninety per cent improvement in lameness after perineural anaesthesia of the palmar metacarpal nerves distal to the carpometacarpal joint in association with an incomplete parasagittal fracture of the third carpal bone and rupture of the medial palmar intercarpal ligament has been observed (Dyson 2013b). Perineural anaesthesia of the palmar metacarpal nerves distal to the carpometacarpal bone has also improved lameness by >70% in horses with abnormal mineralisation of the third carpal bone (Nagy and Dyson 2012). More than 80% improvement in lameness has been seen after perineural anaesthesia of the deep branch of the lateral plantar nerve in association with a frontal plane fracture of the central tarsal bone (Dyson 2013b) or in association with mineralisation of the central or third tarsal bones (Daniel *et al*. 2012; Dyson 2013a).

We therefore advocate that radiographic and ultrasonographic evaluation of the carpus and proximal metacarpal region or tarsus and proximal metatarsal region should be performed routinely after apparently localising pain causing lameness to the proximal metacarpal or metatarsal regions (Dyson 2018b). We also recommend that if a proximal suspensory ligament lesion is identified, the suspensory ligament should be examined in its entirety, because concurrent suspensory ligament branch injuries may coexist, despite an absence of detectable improvement after palmar (plantar) and palmar metacarpal (plantar metatarsal) nerve blocks in the distal third of the metacarpal (metatarsal) region (the so-called 'low-4-point' block) (Marneris and Dyson 2014; Gruyaert *et al*. 2020). We have also observed, as in the report by Pezzanite *et al*. (2020), that some horses with pain originating in the condyles of the third metacarpal bone may have lameness which is not abolished by a 'low-4-point' block, but lameness resolves after perineural analgesia of the palmar metacarpal nerves just distal to the carpus (Dyson 2013b). It was suggested that this may reflect the proximal level at which nerves enter the third metacarpal bone. It may also reflect a combination of condylar pathology and more proximal ligamentar pathology, which may occur concurrently. If routine imaging of the carpus and proximal metacarpal region is negative, then evaluation of the fetlock region may be indicated.

We caution against the use of the medial approach to the lateral palmar nerve to localise pain to the proximal palmar metacarpal region, because of its lack of specificity. Proximal diffusion around the median nerve and the caudal branch of the ulnar nerve may occur (Nagy *et al*. 2012) and result in the potential to anaesthetise the entire carpal region.

We also recommend comparing the response to intra-articular anaesthesia of the middle carpal joint or the

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tarsometatarsal joint alone to the response to the anaesthetic method used to block the proximal metacarpal or metatarsal region (Pilsworth and Dyson 2015). This can be helpful in distinguishing the contribution between carpal or tarsal region pain and proximal metacarpal (metatarsal) region pain. However, in some horses the results are confusing. This was highlighted in a recent retrospective evaluation of MR images of the tarsus and proximal metatarsal region (Barrett *et al*. 2018), in which the site of the most severe pathology did not consistently reflect the results of diagnostic anaesthesia. This topic is discussed in more detail elsewhere (Pilsworth and Dyson 2015).

It is important to bear in mind that stress-related bone injury of the third metacarpal bone (Powell *et al*. 2010; Morgan and Dyson 2012) and bone/ligament interface disruption (Barrett *et al*. 2018a,b) are important differential diagnoses of proximal palmar metacarpal region pain, and radiographic assessment may permit a definitive diagnosis of some primary bone injuries. The clinical features of primary bone injury may differ from those associated with proximal suspensory desmitis ± enthesopathy (Morgan and Dyson 2012; Murray 2019), and scintigraphy or MRI may be required in some horses. Unlike in some other anatomical regions, increased radiopharmaceutical uptake in the proximal aspect of the third metacarpal or metatarsal bones is likely to be of clinical significance, reflecting either primary osseous injury or enthesopathy associated with injury of the proximal aspect of the suspensory ligament (Quiney *et al*. 2018). However, there was a high proportion of false-negative results associated with primary forelimb and hindlimb proximal suspensory injuries (Dyson *et al*. 2007; Quiney *et al*. 2018). In hindlimbs, an association has been recognised with increased radiopharmaceutical uptake and ultrasonographic lesion severity (Dyson *et al*. 2007) or proximal suspensory desmopathy and large tarsal angles (Dyson and Murray 2012).

We strongly believe that ultrasonography is an important tool, and high-quality images provide a reliable method for the diagnosis of proximal suspensory ligament lesions, as verified by histological assessment (Dyson *et al*. 2017). Evaluation of not only the infrastructure of the ligament, but also its size relative to other structures and the space between them is important for assessing ligament injury and the possible presence of adhesions between the suspensory ligament and other soft tissue and osseous structures (Dyson *et al*. 2017, 2018). Although accurate measurement of the cross-sectional area of the proximal aspect of the suspensory ligament is not possible, it is straightforward to assess its size relative to other soft tissue structures and the space between it and the third metacarpal (metatarsal) bone and between it and the accessory ligament of the deep digital flexor tendon. However, we recognise that MRI was superior to ultrasonography for the detection of adhesions (Dyson *et al*. 2018). The potential value of off-incidence imaging of the suspensory ligament should not be overlooked (Werpy *et al*. 2013; Denoix and Bertoni 2015).

We agree with the authors in fully recognising the value of MRI in horses in which radiological and ultrasonographic findings are negative or equivocal, that do not adequately explain the clinical features and degree of lameness, or require further information for management decisions (Nagy and Dyson 2012; Barrett *et al*. 2018a,b; Labens *et al*. 2020). The ability for MRI to evaluate both osseous and soft tissue pathology gives added advantage to previously performed conventional imaging. However, undertaking MRI is not financially feasible for all owners and skilled image acquisition is required for good quality images, whether obtained standing or under general anaesthesia. The recent report of peripheral neuropathy following general anaesthesia for acquisition of MR images of the tarsal and proximal metatarsal region also highlights that this is a procedure not without risk (Moreno *et al*. 2020). Frequently, a management plan can be advised if there is definitive ultrasonographic evidence of suspensory ligament injury and these reflect the clinical findings. In the United Kingdom, we have seen a substantial increase in the frequency of occurrence of hindlimb proximal suspensory desmopathy in sports horses in recent years (2009–2018) compared with 1998–2003 (Gruyaert *et al*. 2020). Hindlimb proximal suspensory desmopathy was identified ultrasonographically in 923 of 2296 horses (40.2%) undergoing orthopaedic assessment.

In conclusion, we feel that accurate history acquisition and careful clinical assessment are mandatory for any lameness assessment and that the ultimate diagnosis should correlate with the severity of the clinical features. There should be a logical and thorough approach to diagnostic anaesthesia, with the expectation that ultimately, in the majority of horses, we should be able to achieve almost complete resolution of lameness. Conventional imaging of both the carpus (tarsus) and metacarpal (metatarsal) region should be routine in horses in which pain is apparently localised to the proximal palmar (plantar) metacarpal (metatarsal) region, with MRI, or targeted scintigraphy, being reserved for those horses in which the results are inconclusive, do not fit with the clinical presentation, or when further information is required for a management plan.

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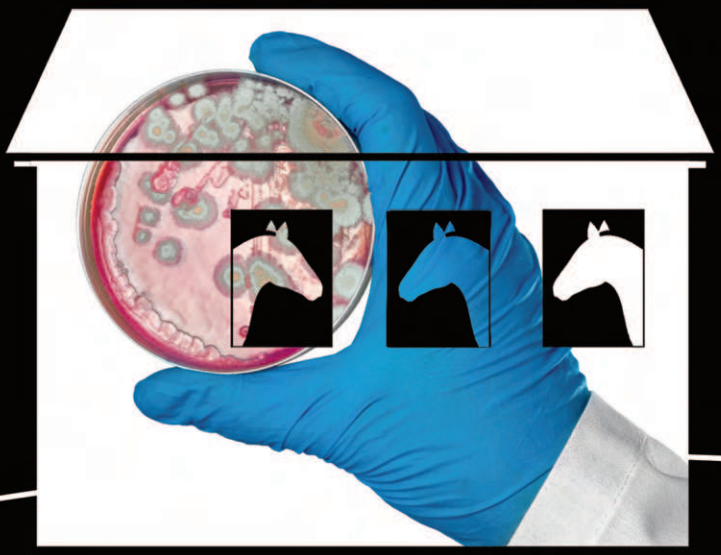

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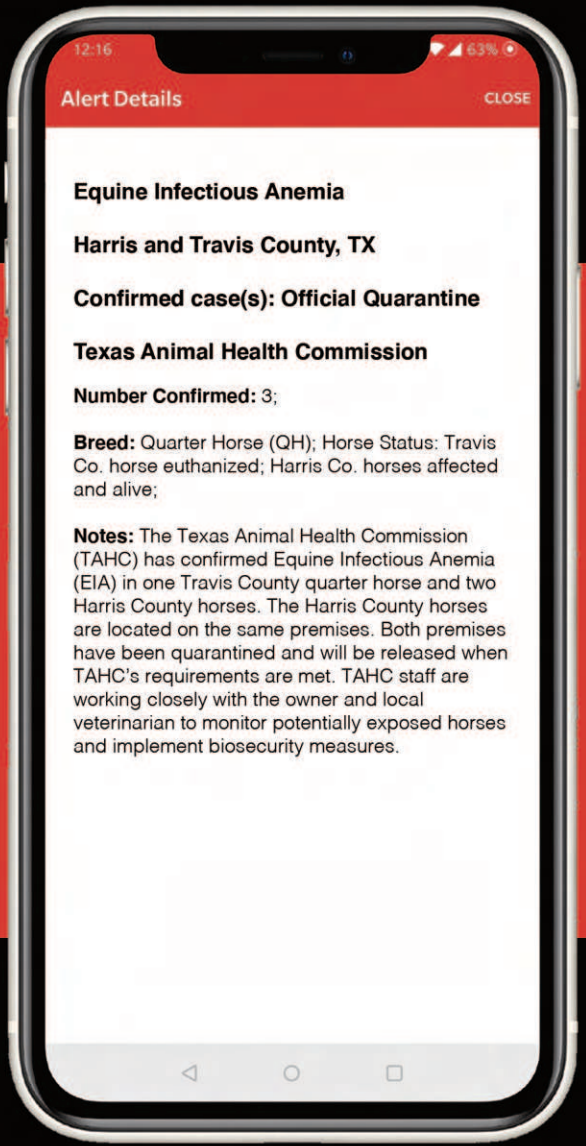

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Correspondence

Response to Drs. Dyson, Nagy, and Murray letter regarding 'Lameness originating from the proximal metacarpus/tarsus: A review of local analgesic techniques and clinical diagnostic findings' [eve.12904]

Dear Editor,

Thank you for the opportunity to respond to the correspondence from Drs. Dyson, Nagy and Murray (Dyson *et al*. 2021) regarding our review article 'Lameness originating from the proximal metacarpus/tarsus: a review of local analgesic techniques and clinical diagnostic findings' (Pezzanite *et al.* 2020). We acknowledge their expertise in this area of lameness diagnosis and thank them for taking the time to enlarge on some aspects of the clinical investigation of lameness originating from this region as described. Overall, we would like to emphasise that we agree with Dyson *et al*. in advocating for a thorough stepwise approach to lameness evaluation including history, musculoskeletal palpation, lameness evaluation, anaesthetic blocking and diagnostic imaging, where severity of lameness matches the ultimate diagnosis. We feel the practices they described are generally reflective of our approach in clinical lameness diagnosis as well. We would like to further expand on several topics mentioned, including per cent improvement following blocking, correlation of clinical findings to blocking patterns and approach to diagnostic imaging.

Defining the minimum per cent improvement following local anaesthetic blocking of the proximal metacarpal/ metatarsal region appears to be the main point of contention between the methods described in our case population and that of Dyson *et al*. When retrospectively investigating our case population in our manuscript, we reported 60% improvement at minimum for localisation of lameness to this region (with further improvement to blocking in other regions in some cases). This is in contrast to the expectation of at least 90% and 80% improvement in fore- and hindlimbs, respectively, suggested by Dyson *et al*., with residual lameness being abolished by ulnar or tibial nerve blocks. We would like to first acknowledge that assigning per cent improvement is subjective and differs between clinicians. In this manuscript, the minimum cut-off of 60% was used due to the retrospective nature of collecting and evaluating data via medical records where multiple clinicians observed lameness at different and inconsistent time points following blocking in many instances and emphasise that additional improvement was seen in other regions in some cases (i.e. the reported 60% was for the region of the proximal metacarpal or metatarsal regions). While additional lameness may arise from another region of the limb and/or further improvement may be seen with the addition of a tibial nerve block, in our hands, a 60% improvement warrants further investigation of that area. Finally, we feel it is likely that differences in blocking patterns and per cent improvement between our population and that described by Dyson *et al*. may, in part, be attributed to differences in athletic discipline and specific lesions commonly diagnosed (e.g. enthesopathy component in our Western performance horse population vs. desmopathy), which we will discuss further. In summary, we also advocate for striving for greater than 60% overall improvement in all cases, with an aim towards almost complete resolution of lameness.

Specific clinical features including lameness severity and response to musculoskeletal palpation should correspond to the final diagnosis. It is our clinical impression that there are significant differences between our case population and that treated by Dr. Dyson *et al*., as our population contains a high proportion of Western performance horses. A study recently published by our group evaluating Western performance horses using magnetic resonance imaging revealed that enthesopathy is a more common feature of proximal suspensory disease than desmopathy in this subset of horses, with third metacarpal (McIII) sclerosis at the proximal suspensory ligament (PSL) origin in 42/44 (95%) and McIII resorption at the PSL origin in 32/44 (73%) cases examined (Barrett *et al*. 2018). Previous studies by Brokken *et al*. (2007) and Nagy and Dyson (2012) further support the observation that types and frequency of proximal metacarpal/metatarsal injuries differ between case populations and that diagnosis of these has been enabled by the use of MRI. Our clinical impression and experience are that horses with osseous involvement may not improve as much to analgesia of the proximal metacarpal/ metatarsal region compared to horses with primary desmopathy. This may contribute to lower per cent improvement in some cases with osseous involvement. We agree that additional improvement above 60% would be necessary to definitively localise lameness solely to the proximal metacarpal/metatarsal region but would advocate for further investigation of the region with diagnostic imaging when 60% improvement is achieved. Since the original publication of this manuscript online in 2017, we have further advocated for the implementation of 'cross-blocking', or intra-articular analgesia of the distal intertarsal and tarsometatarsal joints in the hindlimb, and middle or radiocarpal joints in the forelimb, following incomplete response to blocking of the proximal metatarsal/metacarpal regions. We further support the practices of comparing intra-articular analgesia alone to perineural blocking of the region or moving proximally to perform ulnar or tibial nerve blocks as described by Dyson *et al*. if further resolution of lameness is indicated.

The selection of diagnostic imaging modalities following improvement to local anaesthetic blocking of the proximal metacarpal/metatarsal region warrants further discussion. We feel that our clinical practice is reflective of Dyson *et al*.'s comments regarding initial investigation of the region with radiographs and ultrasound following lameness localisation. We support further evaluation with magnetic resonance imaging as dictated by the client's financial capabilities in cases where the degree of lameness, clinical features or

response to treatment are not explained sufficiently by radiographic or ultrasonographic findings. It was not our intention to imply that MRI (or other advanced imaging techniques such as computed tomography, nuclear scintigraphy) should be performed before or in lieu of traditional imaging techniques, which is further supported by the fact that MRI was only performed in 17 or 14% of our cases where lameness was localised to this region over the time period investigated for fore- and hindlimbs, respectively, and that radiographs and ultrasound were also performed in those cases. However, it is our clinical experience that the ability to evaluate both osseous and soft tissues structures using MRI is unparalleled by other more conventional imaging techniques for this region in particular and advocate its use in cases where indicated and feasible, as described above.

In summary, we would like to thank Dyson *et al*. for their expansion on this topic in their letter to the editor. If lameness improves at least 60% following perineural analgesia of the proximal metacarpal or metatarsal region, we advocate imaging of that region but would also continue diagnostic blocking until a greater percentage of lameness (80% or more) is achieved. Additionally, per cent improvement following local anaesthetic blocking may be less in cases with a significant component of enthesopathy and therefore should be considered in the context of the athletic discipline of the horse evaluated. Following lameness resolution to blocking of the proximal metacarpal/metatarsal region, radiographic and ultrasonographic evaluation is indicated, followed by advanced imaging when in cases where clinical features, lameness severity and/or response to treatment are not explained by first wave diagnostics. We feel that the opportunity to discuss and expand upon the differences in the case populations, disciplines, and in turn anatomical lesions, of the horses that we serve, is important towards furthering the industry's understanding of conditions arising from the proximal metacarpal/metatarsal region.

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